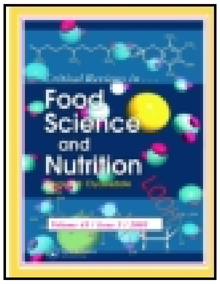

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Instant Noodles: Processing, Quality and Nutritional Aspects

Neelam Gulia [a] , Vandana Dhaka [a] & B. S. Khatkar [a]

[a] Department of Food Technology , Guru Jambheshwar University of Science and Technology , Hisar

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Neelam Gulia, Vandana Dhaka and B. S. Khatkar*

Department of Food Technology

Guru Jambheshwar University of Science and Technology, Hisar

Corresponding Author*: B. S. Khatkar, Department of Food Technology, Guru Jambheshwar University of Science and Technology, Hisar, Haryana-125001, India

E-Mail*: bhup2009@hotmail.com

Fax: +91-1662-263313; Tel. No.: +91-1662-263313

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Abstract

Noodles are one of the staple foods consumed in many Asian countries. Instant noodles have become internationally recognized food and worldwide consumption is on the rise. The properties of instant noodles like taste, nutrition, convenience, safety, longer shelf-life and reasonable price have made them popular. Quality factors important for instant noodles are colour, flavour, and texture, cooking quality, rehydration rates during final preparation and the presence or absence of rancid taste after extended storage. Microstructure of dough and noodles has been studied to understand the influence of ingredients and processing variables on the noodle quality by employing scanning electron microscopy (SEM). Applications of newer techniques like confocal laser scanning microscopy (CLSM) and epifluorescence light microscopy (EFLM) employed to understand the microstructure changes in dough and noodles have also been discussed. Sincere efforts of researchers are underway to improve the formulation, extend the shelf life and promote universal fortification of instant noodles.

Accordingly, many researchers are exploring the potential of noodle fortification as an effective public health intervention and improve its nutritional properties. This review focuses on the functionality of ingredients, unit operations involved, quality criteria for evaluation, recent trends in fortification and current knowledge in relation to instant noodles.

INTRODUCTION

It is believed that Asian noodles originated from China as early as 5000 BC (Fu, 2008; Hou and Kruk, 1998). Momofuku Ando invented "Chicken Ramen™", the world's first instant noodle product manufactured by Nissin Foods, Japan in 1958. His accomplishment brought a revolution in culinary culture. Another achievement was the introduction of Cup noodles by Nissin in 1971. Instant noodles are made from wheat flour, starch, water, salt or kansui (an alkaline salt mixture of sodium carbonate, potassium carbonate, and sodium phosphate), and other ingredients that improve the texture and flavour of noodles, partially cooked by steaming and further cooked and dehydrated by a deep frying process (Kim, 1996a). Pasta and noodles, both are wheat-based products but they differ depending on the country of origin, raw materials, formula ingredients, manufacturing procedure as well as their consumption patterns (Hou, 2001; Hou and Kruk, 1998). Pasta products are made from coarse semolina milled from durum wheat (*Triticum durum)* which is mixed with water and then extruded through a metal die under pressure. However, the noodles are prepared using wheat flour of either hard or soft wheat (*Triticum aestivum)* along with water, salt and alkaline salts (Kansui). Noodle manufacturing involves sheeting and cutting of dough which allows lower water addition as compared to other bakery products (Corke and Bhattacharya, 1999; Miskelly, 1993). The properties of instant noodles like taste, nutrition, convenience, safety, longer shelf-life and reasonable price have made them popular worldwide. Instant noodles are also used as space and emergency food.

Instant noodles are consumed in more than 80 countries and have become internationally recognized food. Noodle industry supplies 95.4 billion servings annually to consumers throughout the world and the demands are on the rise (Fig. 1). Worldwide, China ranks first in the consumption of noodles followed by Indonesia, Japan and Vietnam according to the world instant noodle association (WINA, 2011) (Fig. 2). Although consumption of noodles in India had been low, however, it has increased appreciably in the past five years i.e. by more than 5 times as reported by WINA (2011), with current consumption of 2,940 million packets (Bags/Cups) (Fig. 3).

TYPES OF INSTANT NOODLES

Instant noodles are classified into two types on the basis of methods used for the removal of moisture i.e. instant dried noodles and instant fried noodles (Fig. 4). Instant dried noodles are produced in a fully automatic production line similar to the type used for steamed and deep-fried noodles, except that a continuous drying chamber replaces the deep fryer, using hot air as the drying medium. Frying the noodles in oil decreases the moisture content of noodles to about 2-5% while in hot air dried noodles it is about 8-12%. The heating during frying or hot air drying further gelatinizes the starch and the noodles attain a porous texture which facilitates rehydration process while cooking the product. Frying is the preferred method of drying and more than 80% of instant noodles are fried because hot air drying results in uneven drying that adversely affects the texture of the finished noodles, requires a longer cooking time and lacks the distinctive flavour introduced by deep-frying. The disadvantage of frying, however, is that fried noodles contain about 15-20% oil (compared with a maximum of 3% fat in hot air-dried noodles), are more susceptible to oxidation resulting in rancidity and have health issues due to higher fat content. The use of antioxidants, however, prolongs the shelf life of fried instant noodles.

Instant noodles based on their commercially packaged form available are Bag type and the Cup type noodles. Bag type noodles are available with the sachet of seasonings packed within and usually cooked in constantly boiling water for about 3-4 min before serving. Cup noodles are instant noodles in a waterproof polystyrene cup with the seasoning sprinkled over the noodles and are ready to serve after pouring hot water into the bowl and resting for 2–3 min. The basic processing for bag and cup type noodles is similar. There do exist, however, some differences in the processing of these two types of noodles. For example, the noodle strands of cup noodles are usually thinner to facilitate the rehydration rate, starch is usually included in the formulation and they are fried for a longer time as compared to bag type counterparts.

FUNCTIONALITY OF RAW MATERIALS/ INGREDIENTS

The main ingredients for instant noodles are wheat flour, salt or kansui (alkaline salt mixture of sodium carbonate, potassium carbonate, and sodium phosphate) and water. Other ingredients like starch, gums, emulsifiers, stabilizers, antioxidants, colouring and flavouring agents are also added to improve the texture, eating quality and shelf life of instant noodles (Table 1). Nowadays, instant noodles are also fortified with protein, minerals and vitamins to improve their nutritional value.

Wheat Flour

The preferences for colour, texture and eating quality of noodles varies widely in different countries and thus, wheat flour specifications also vary (Wills and Wootton, 1997). Xue et al. (2010) investigated that about 68% of the variability in sensory properties in instant noodles could be explained by the chemical composition of flour and physical properties of dough. Thus, the key to produce a quality product is intelligent selection of wheat flour with desired qualities. The flour used for noodle preparation is obtained from sound wheat grains free from sprout damage with ash content of 0.5-0.6% and medium protein content of 10-12.5%. Milling extraction rate, flour colour and polyphenol oxidase (PPO) directly affect the colour of final product (Baik et al., 1995; Ye et al., 2009). Ash content negatively correlates with the brightness of noodles (Zhang et al., 2005b).

Adequate dough strength and extensibility is crucial for noodle flour in order to withstand sheeting, resist tearing, breakage and shrinking of dough sheet. Both protein quality and quantity influence characteristics of instant noodles including fat absorption, colour, and textural quality, as well as dough properties like water absorption and colour. Flour protein content has a positive correlation with cooked noodle firmness and a negative correlation with noodle brightness (Asenstorfer et al., 2010; Wang et al., 2004). Instant noodles prepared from flour of higher protein content and higher SDS-sedimentation value exhibit lower fat absorption (Moss et al., 1986; Park and Baik, 2004b). Variations in gluten properties (as indicated by farinograph parameters or SDS sedimentation volume) were found to have significant effects on noodle firmness, elasticity, and smoothness (Baik, 2010; Baik et al., 1994; Huang and Morrison, 1988). The viscoelasticity of heat-treated gluten, isolated with 2% NaCl solution significantly correlated with gluten strength and Chinese white salted noodle texture and can be used for predicting white salted noodle quality (Kovacs et al., 2004). Yanaka et al. (2007) reported that dough strength conferred by high molecular weight glutenin subunit allele, Glu-D1d allele affects the firmness of cooked noodles. Yamauchi et al. (2007) also confirmed that good noodle texture (hardness and elasticity) is associated with strong proteins (having HMWGS 5+10, 17+18) and high protein contents.

Starch properties are also important in determining quality of noodles as their texture depends largely on gelatinized starch (Bushuk, 1998). Variations in starch properties have been found to play a major role in noodle softness and viscoelastic properties (Crosbie, 1991; Konik et al., 1992, 1993; Yun et al., 1997). Pasting characteristics (Oda et al., 1980; Zhang et al., 2005a), peak viscosity (Bhattacharya and Corke, 1996), flour swelling volume (Crosbie, 1991), amylose-amylopectin ratio, and damaged starch (Oh et al., 1985a) determine the noodle properties. Flours with low gelatinization temperatures are preferred for rapid hydration during cooking. Higher starch damage is associated with poor noodle colour, undesirable high cooking loss and excessive surface swelling (Hatcher et al., 2002). The fine particle flour with lower starch damage, therefore, results in good cooking quality of noodles. The rheological properties of raw white salted noodle (WSN) have been found to be mainly influenced by the size of starch granules, where the small starch granules exhibited high amounts of water absorption during dough preparation and a dense packing of starch granules inside a thin gluten-strand network. However, the rheological properties of cooked WSN were mainly dominated by the amylose content and fine structure of the amylopectin, which resulted in the differences in water absorption and cooking time required for cooked WSN (Huang and Lai, 2010).

Flour swelling volume reflects swelling/gelatinization potential of flour and the dosage of granule bound starch synthase (GBSS) gene (Bettge, 2003; Zeng et al., 1997). GBSS gene located at chromosome 4A is associated with amylose synthesis (Sano, 1984) and its absence results in higher swelling volume and better noodle quality (Guo et al., 2003; Zhao et al., 1998). Briney et al. (1998) targeted the GBSS gene and identified a 440 bp PCR band, corresponding to presence/absence of the gene, which can be used to select the genotypes having good noodle quality. Batey et al. (1997) observed a significant negative correlation between the amount of degree of polymerization (DP) 5 oligosaccharide and noodle eating quality and concluded that the size of the HPLC peak corresponding to this oligosaccharide may be used as a rapid method of screening for noodle-making quality. The results also suggested that the structure of the amylopectin in starch of good noodle-making wheats has relatively few branch points close together. The optimum amylose content was observed to be about 22% for good quality Japanese noodles, with starch of higher or lower amylose content coming from flour of lower noodle-making quality. Waxy wheat flours and reconstituted flours with <12.4% starch amylose content exhibited undesirable characteristics for preparing instant noodles due of higher fat absorption, darker color, poor surface appearance, and extremely soft texture of cooked noodles, despite shorter cooking time and more cohesive texture than instant noodles of high starch amylose content (Park and Baik, 2004c). Crosbie et al. (2002) described a shortened temperature program method using Rapid Visco Analyser for prediction of noodle quality of wheat flours in which peak viscosity and breakdown correlated significantly with total score of ramen.

Processing of wheat dough during instant noodle preparation and storage alters the enzyme-resistance of starch. Dhital et al. (2010) studied the effect of processing and storage conditions of instant noodles on formation of resistant starch (RS). It was seen that dough forming operation did not contribute significantly to the formation of RS; however, steaming of the noodle strand under pressure, frying and storage time increased RS content of noodle. The rate of increase and quantity of RS was higher at refrigerated condition compared to that of room temperature. It was concluded that the gelatinized and fragmented amylose molecules undergo molecular re-association or retrogradation during storage, which results in increased RS content. Further, the retrogradation process may occur rapidly in the beginning and slow down with time.

Water

Water is another essential ingredient which is necessary for gluten formation which provides viscoelastic properties to dough required for noodle processing. The amount of water needed for noodle processing is optimized to hydrate the flour and develop a uniform dough sheet. The optimum water absorption for noodle is affected by protein content, protein quality, damaged starch, and other physical properties of flour (Park and Baik, 2002). The water absorption level recommended for noodle processing is about 30- 38% based on flour weight. Water absorption level has a major impact on the amount of work required in processing as well as colour. There was a significant decline in textural characteristics with increasing water absorption (Edwards et al., 1996; Hatcher et al., 1999; Park and Baik, 2002). Sheeting, cutting and drying of noodles become difficult when water absorption deviates more than 2-3% from the optimum level. Insufficient water results in non-cohesive stiff dough and less extensible noodle sheet while too much water results in dough stickiness handling problems during processing (Hatcher et al., 2008c). Optimum water absorption can be determined using a mixograph or farinograph (Oh et al., 1986; Seib et al., 2000) and by experienced personnel on the basis of dough handling properties.

Salt and Alkaline reagents

The amount of salt added in noodles is usually 1–3% of flour weight. Salt has strengthening and tightening effect on the gluten, which may be due to its inhibitory effect on proteolytic enzymes, or by direct interaction of the salt with flour proteins. Thus, it significantly improves sheeting properties of dough, especially at high water absorption levels. Incorporation of salt reduces cooking time, enhances flavour, provides softer but more elastic texture, and inhibits enzyme activities and the growth of micro-organisms (Fu, 2008).

Alkaline salt can be used alone or in combination with different salts, depending on local preference. The most commonly used alkaline salts are sodium and potassium carbonates. Other alkaline reagents, such as sodium hydroxide and bicarbonates are also used in some countries. The type of alkaline salt used also affect the quality of noodles (Hatcher et al., 2008c). Addition rates of alkaline salts are 0.5–1.5% for noodles with strong alkaline flavour and, 0.1–0.3% as a quality improver for instant noodles. The unique yellow colour associated with addition of alkaline salts in common wheat used for noodle preparation is due to endogenous flavonoids undergoing a chromophoric shift, i.e., turning yellow, in the presence of alkali (Asenstorfer et al., 2006; Hatcher et al., 2008b). The changes in dough characteristics associated with alkaline pH fundamentally influence the behaviour of the gluten proteins resulting in tougher, tighter, and less extensible dough. The toughening of dough with alkali addition has a very significant impact on the processing properties and the texture of the final products. The addition of alkali increases water absorption potential of noodle dough, gives noodles a firmer texture, increases both the breaking and cutting forces of noodles (Sung and Sung, 1993), retards starch gelatinization and increases starch paste viscosity (Bean et al., 1974; Terada et al., 1981). Ong et al. (2010) found that glutenin macropolymer (GMP) extracted from alkaline dough was gummy, sticky, more opaque and had higher gel strength than that from salted dough. GMP gel strength also increased significantly after dough resting in alkaline dough suggesting the role of GMP in increasing dough stiffness.

Fat/Oil

Oil represents about 20% of the total weight of the final product. The most common frying oil used in Asia is palm oil because of its good frying performance, heat stability, availability and relatively low cost. Partially hydrogenated soybean and canola oil can also be used for frying. Frying oil has a significant effect on the flavour of instant noodles; the frying oil should be of good quality. During frying, the quality of oil deteriorates as a result of chemical reactions, prolonged and continuous heating which may pose food safety concerns and sensory failures. Therefore, heat stability is a major concern in selecting frying oil. The quality of frying oils can be judged by its colour, flavour, free fatty acids, peroxide value, iodine number, melting point, and smoke point.

Improvers and Preservatives

Polyphosphates, hydrocolloids, emulsifiers, antioxidants and starches are commonly used as additives to improve product quality in noodle processing. Various additives used in instant noodles along with their functional properties have been presented in Table 2.

In the dough system, polyphosphates act as chelating agent, modify the dough processing properties and retard the discoloration process of fresh noodles. Polyphosphates accelerate gluten bonding which improve noodles elasticity, flexibility, texture and chewing properties; facilitate the starch gelatinization during cooking allowing more water retention in the noodle and reduces water cloudiness while cooking (Hourant, 2004). They are dissolved in water before the mixing of the dough and their usage rate is typically 0.1% of flour weight.

Hydrocolloids such as guar gum, locust bean gum, alginates and carboxymethyl cellulose (CMC) are widely used in instant noodle processing. The addition of gums (0.1–0.5%) improves rehydration characteristics of noodles during cooking, modifies the texture and overall ‘‘mouth-feel” of finished product and decreases the fat uptake during frying of instant noodles as they are hydrophilic and have high water binding capacity. Gum and starch improved the binding and mechanical network in the dough. Insufficient water in the dough apparently reduced cohesion in the dough whereas excess water reduced the functionality of gum and starch (Yu and Ngadi, 2006). Choy et al. (2010) examined the effects of varying microbial transglutaminase (MTGase), sodium stearoyl lactylate (SSL) and water on product texture and colour of instant noodles. MTGase and SSL improved the textural properties of noodles prepared with the low-protein flour due to enhanced development of structure within the noodles with no significant difference in noodle colour. MTGase and water also affected fat uptake with an inverse relationship between water incorporation and uptake. Choy et al. (2012) also reported that the combined use of acetylated potato starch (APS) and carboxy methyl cellulose (CMC) primarily affects the textural attributes of hardness and adhesiveness, rather than other quality parameters of instant noodles. However, addition of CMC alone had a negative impact on the cohesiveness values of cooked instant noodles with minimal effects on stickiness and fat uptake while APS enhanced noodle hardness without significantly affecting the cohesiveness values. It was concluded that APS can be used as an ingredient for enhancing noodle eating quality in case of lower protein wheat flours.

Lee et al. (2008) studied the effects of addition of alginate on physicochemical, rheological and noodle-making properties of wheat flour. With the addition of alginate, noodles exhibited an increase in cooked weight, cutting and tensile forces, and yellowness while there was a decrease in cooking loss, lightness and redness. Carotenoids and flavonoids pigments of wheat and alkaline reagents contribute to colour of noodles. Natural and synthetic colours are also used to enhance the colour. Food colorants such as β-carotene are often used in the formulation of udon noodles to adjust the creamy yellow colour. Tartrazine is commonly added to intensify the yellow colour of Hokkien noodles in Southeast Asia (Crosbie and Ross 2004). Natural colouring agents, such as vitamin B2 are used in addition to kansui to fulfil consumer's preference of having lower amounts of alkaline salts in yellow Chinese alkaline noodles.

Organic acids are used to prevent colour change and inhibit microbial deterioration. Emulsifiers such as glycerine fatty esters, monoglycerides (MG) sucrose fatty ester (SFAE) and lecithin are incorporated to prevent starch retrogradation, improve texture and structure, and improve cooking quality. Extruded noodles with sodium stearoyl lactylate (SSL) improved tensile strength, cutting force and elasticity, whereas the addition of lecithin, MG or SFAE had a negative impact on the strength of extruded noodles (Shiau, 2004).

Steamed and deep-fried instant noodles have a high fat content of 15–22%, and oxidative rancidity is the major factor limiting shelf life. Antioxidants like butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tertiary- butylhydroquinone (TBHQ) are widely used to overcome rancidity problems in the finished product. Of these, TBHQ has been shown to have best antioxidant activity (Fu, 2008). TBHQ is regarded as the best antioxidant for protecting frying oils against oxidation and, like others, it provides carry-through protection to the finished fried product (Dobraszczyk et al., 2006).

Various enzymes i.e. transglutaminase, lipases, oxidoreductase, and amylases have also been included in formulations of instant noodles, primarily to enhance the texture of the noodles. Transglutaminase increases break strength of uncooked dried noodles as well as firmness of cooked noodles by forming glutamyl-lysine cross links in gluten. Transglutaminase induces the formation of high molecular weight polymers, despite the low lysine content in gluten proteins; reinforces the network structure; modifies the gluten viscoelasticity and also improves thermal stability of gluten during processing (Motoki and Seguro, 1998). Wang et al. (2011) observed that addition of transglutaminase (TGase) improved the rheology and processing properties, cooking quality as well as elasticity of noodles prepared from oat dough containing exogenous proteins (vital wheat gluten and egg albumin), thus, suggesting that TGase can be utilized for developing gluten free noodles and enhance the quality of noodles from non-wheat flours. Lipases have been stated to reduce surface stickiness and increase firmness of cooked noodles. Oxidoreductases such as glucose oxidase on the other hand not only increases noodle firmness, but also reduce stickiness and cooking loss in noodles. Surface application of amylases is proposed to reduce the surface stickiness in packaged as well as precooked noodles (Crosbie and Ross 2004). However, addition of alpha-amylase in white salted noodles resulted in undesirable soft texture (Cato et al., 2006).

ROLE OF CRITICAL UNIT OPERATIONS

Noodle processing typically comprises of mixing raw materials, resting the crumbly dough, sheeting the dough into two dough sheets, compounding the sheets into one, gradually sheeting the dough into a specified thickness and slitting into noodle strands. For instant noodles preparation, strands are steamed and dehydrated by drying or frying followed by cooling and packaging with the seasonings.

Mixing

Ingredients other than flour are predissolved in water, stored at 20-30ºC while salt water can be prepared separately. Wheat flour and water along with other weighed ingredients are mixed first at high speed and then at low speed, giving a total time of 15-25 minutes in industries while at laboratory scale researchers have used a mixing time of 4 to 5 minutes (Park and Baik, 2004b; Wu et al., 2006; Yu and Ngadi, 2004). The mixing time, however, also depends on the type of mixer used. In contrast to bread processing, function of mixing for noodles is to distribute the ingredients uniformly and to hydrate the flour particles. There is little gluten development during the mixing stage in flour having low water absorption capacity. The degree of gluten development, however, is significant in high water absorption dough (>35%) with long mixing time (>15 min). Mixers commonly used in the noodle industry include horizontal mixer, the vertical mixer, continuous high-speed mixer, low-speed super mixer and the vacuum mixer. Mixing is also influenced by the quality of flour, volume of water added, presence/absence and amount of certain ingredients (especially salt and alkaline salt), and temperature and humidity of processing environment. Flour of high protein content and damaged starch tends to produce larger dough crumbs during mixing that may result in uneven hydration (Azudin, 1998). Mixing is usually followed by dough resting. This step allows the crumbly mixture to rest for a period of time to accelerate further hydration of flour particles and to redistribute water in the dough system. Resting improves processing properties and facilitates gluten formation during sheeting.

This is achieved by the relaxation of the gluten structure already formed during mixing. At commercial level, resting facility is usually provided between the mixer and the first pair of sheeting rolls. Resting is carried out by mixing dough at very low speed (5–8 rpm) for 10– 20 min. Mixing at low speed avoids the formation of large dough pieces during resting and also serves feeding of the sheeting rolls in the continuous process. Resting also determines the degree of starch gelatinization during steaming (Wu et al., 1998).

Sheeting

After mixing, the crumbly dough is compressed to form continuous dough sheet which is folded or compounded and passed through subsequent rolls. The sheeting process is intended to achieve a smooth dough sheet with desired thickness, and a continuous and uniform gluten matrix in dough sheet. At the sheeting stage, number of passes through rolls, roll diameter, sheeting speed and reduction ratio are the main factors affecting dough sheet characteristics. The thickness of dough sheet is reduced gradually to avoid damage to the surface and gluten structure which is controlled by roll gap settings in a series of smooth rolls. With each successive pass, the roll diameter should decrease gradually so that compression distance and pressure are also reduced. Dough sheets are rested to allow gluten structure relaxation or mellow the gluten and make it more extensible by slow passage on a zigzag conveyor in automated plants.

Cutting/ Slitting and Waving

The dough sheet is cut into noodle strands of desired width with a slitter. The width and shape of noodle strands are determined by cutting rolls. Noodles can be either square or round in shape according to various slitters used. In case of instant noodle production, noodle strands are continually fed into a travelling net conveyor which moves slower than the cutting rolls above it.

The speed differential between noodle feeding and net travelling results in a unique waving of noodle strands. For instant noodles, the cutting rolls are numbered from 18-22. Numbering represents the number of edges on a piece of 30 mm wide sheet. For example, a Number 18 cutting roll has 18 edges that result in a noodle strip width of about 1.7 mm**.** Noodle strands are cut into a desirable length by a cutter.

Steaming and Molding

The cut and wavy noodle strands are conveyed to a steam chamber to cook them by exposing to a temperature of 100 ºC for 1-5 minutes. The degree of cooking during steaming is critical and depends on the original moisture content of noodle; amount, pressure and temperature of steam; and steaming time. Under-steamed noodles will have a hard core and will be difficult to cook properly while over-steamed noodles are soft and sticky. Steaming is a key process in the manufacture of instant noodles. A high degree of starch gelatinization is required for the production of hot-air dried instant noodles. Superheated steam at high temperature can be used to partially cook, rapidly drying them, thus, creating an instant noodle without the necessity of frying in oil (Pronyk et al., 2008). Steam cooking of starch-water mixture triggers a number of physico-chemical and functional changes in starch granules, such as the loss of granular structure associated with melting of crystallites and underlying helices, and the generation of an amorphous structure (Dhital et al., 2010). The degree of starch gelatinization determines noodle rehydration rate, firmness and viscoelasticity, and is mainly controlled by the steaming process. Steaming time is longer for hot-air dried noodles than for deep fried noodles. Excessive swelling of starch on the noodle surface, which causes many processing problems, should be avoided during steaming in instant noodle production. Noodles cooked by steaming are cooled and extended to separate the strands, and cut into one serving size. Weight of noodles is regulated by the number of strands produced by cutting rolls and length of strands. Noodles strands are further folded before cutting for the square type products. The cut noodles are placed in molder of square, round, bowl or cup shape depending on desired product shape before moving to the frier or drier.

Frying/Drying

After steaming and molding, noodle blocks are fed into frying baskets which are mounted on the travelling chain of a tunnel fryer. The baskets filled with noodle blocks are immersed in hot oil for deep-frying. Dehydration of the exterior surface drives water to migrate from the interior to the exterior of the noodle strands. Eventually, some of the water in the noodles is replaced by oil (Dana and Saguy, 2006). Many tiny holes are created during the frying process due to mass transfer, and they serve as channels for water penetration upon rehydration in hot water. The frying temperature and time are usually varied from 140 to 160ºC, for 60 to 120 s, respectively. The cup noodles are fried at a higher temperature and longer time as compared to bag type noodles. The frying process should be optimized to obtain fried noodles with good sensory properties, low fat content, and low fat decomposition products. Deep-frying of noodle removes moisture, incorporate oil into noodles, gelatinize starch before the free water is evaporated, and create both external and internal porous structures in the noodle which facilitates rehydration.

Noodles drying can also be done by hot air to produce instant dried noodles. Frying is the preferred method of drying as non-fried instant noodles require a longer cooking time. The lesser fat content in case of instant dried noodle makes them attractive. Elimination of oil in the drying of instant noodles may alleviate health concerns about the fat content and presence of trans fatty acids from partially hydrogenated and hydrogenated oils while providing the consumer with a convenient and healthy food product. But the acceptance of dried instant noodles is largely dependent on obtaining good textural properties and eating quality.

Packaging

Frying or drying is followed by cooling the product to room temperature in order to avoid rapid oxidation and other changes. The cooled noodles are packed into a bag along with a soup base sachet. While for the cup noodles, powdered soup base is sprinkled over the noodles and sealed with shrink film. Seasonings and dehydrated vegetables are included in soup base. Higher fat content make the noodles susceptible to oxidative changes and development of rancid flavour. Thus, proper packaging plays important role in extending the shelf life of the product. The onset of rancidity can be delayed by addition of antioxidant in the frying medium. The rancidity of instant noodles is also accelerated in the presence of ultraviolet light; hence noodles are essentially packaged in reddish yellow or green packaging material without any transparent parts. The packaging material used for noodles are polypropylene or polyethylene film for bag noodles and polyester for cup noodles.

QUALITY CRITERIA OF INSTANT NOODLE

Quality factors important for instant noodles are colour, flavour, texture, cooking quality, rehydration rates during final preparation and the presence or absence of rancid taste after extended storage. Sensory evaluation of noodles is carried out to judge the quality and acceptability of the final product. Table 3 represents the evaluation criteria used for judgement of instant noodle quality at various stages of processing. Quality parameters for noodle quality like texture and colour assessed using instrumental analysis correlates well with sensory evaluation results (Hatcher et al., 2008a; Ross, 2006; Tang et al., 1999; Xue et al., 2010; Yun et al., 1997) and are valuable research tools well suited for monitoring noodle texture after changes in formulations, raw materials, and processing.

Colour and Flavour

A bright and light yellow colour is desirable for instant noodles (Kim, 1996a; Kubomura, 1998). Colour is usually measured by spectrocolorimeter (like HunterLab colorimeter) in terms of L* (noodle brightness or lightness), a* (noodle redness) and b* (noodle yellowness) colour scale. L* of instant noodles positively correlates with SDS sedimentation volume and negatively with proportion of alcohol and salt soluble proteins of flour. Protein quality parameters also exhibit a significant relationship with b* of instant noodles (Park and Baik, 2004b). Processing factors like steaming, frying or drying and oil absorption affect the colour of noodles as indicated by the negative correlation of noodle dough sheet lightness (L*) in comparison to positive correlation with L* of cooked instant noodle with the flour protein content (Park and Baik, 2004b). Alkaline reagents also give a yellowish tinge to the noodle colour. Flour ash content (Lee et al., 1987; Oh et al., 1985b) and PPO activity (Kruger et al., 1994) influences mainly noodle whiteness.

Flavour is an important parameter governing instant noodle quality. Oil quality is the major determinant of flavour in instant fried noodles as it is responsible for imparting a distinct flavour to noodles.

Texture

Kubomura (1998) described the texture of instant noodles as rubbery, firm, or smooth. Sensory and instrumental methods are used for the evaluation of noodle texture (Hou et al., 1997; Lee et al., 1987; Oh et al., 1983). Textural parameters frequently used for noodles include smoothness, softness, hardness/firmness, stickiness, cohesiveness, elasticity, chewiness and gumminess (Baik et al., 1994; Konik et al., 1993; Yun et al., 1997). Instrumental measurement of cooked noodle texture is reliable and convenient alternative to the sensory evaluation (Hou et al., 1997; Kovacs et al., 2004; Lee et al., 1987; Oh et al., 1983). The basic methods used are compression including simple compression and texture profile analysis (TPA) and tensile tests. TPA provides a number of textural characteristics like chewiness, hardness or firmness, gumminess and cohesiveness in a single test and is similar to the chewing in mouth. The textural preferences for noodles are generally region specific. Texture of noodles is a complex characteristic which depends on flour quality, water absorption, ingredients used like salt or alkaline reagents as well as processing parameters like sheeting, steaming and dehydration method used. Many researchers have reported methods and probes for determination of texture for noodles (Lee et al., 2002; Oh et al., 1983, 1985a; Ross, 2006; Smewing, 1997). Ross (2006) has reviewed different methods used for textural analysis of noodles. Quick-boiling noodles tend to lose their firmness due to overcooking of their surface. Thammathongchat et al. (2005) attempted to overcome this problem, and developed a new type of processed udon noodle that is pre-cooked (gelatinized) only in the centre, leaving the surface uncooked (ungelatinized) thus, maintaining good texture and firmness because of its ungelatinized surface. The steps included steeping in water, drying the surface, sealing in a plastic pouch, and heating, guided by the concepts of ceiling water content and terminal extent of gelatinization.

Microstructure of dough and noodles has been studied widely to understand the influence of ingredients and processing variables on the noodle quality by employing scanning electron microscopy (SEM). Microstructure differences at the dough stage of instant noodles were observed to be similar to cantonese noodles (fresh alkaline noodles). Microstructure changes affected by additional processes of steaming, frying and final cooking were also reported (Moss et al., 1987). Confocal laser scanning microscopy (CLSM) was used by Chewangkul et al. (2001) to study changes in microstructure during instant noodle production and they regarded it as a potential tool for monitoring microstructure differences resulting from varied processing conditions. Huang and Lai (2010) used CLSM for studying the effect of different cereal starches on noodle quality. Epifluorescence light microscopy (EFLM) followed by further image processing has also been reported as a useful technique for dough microstructure studies and the counter staining procedure can be applied for simultaneously detection of gluten and starch in wheat dough system to better understand the relationships of dough components (Peighambardoust and Dadpour, 2010). Bellido and Hatcher (2010) found ultrasonic technique as a simple and reliable way to determine important textural parameters of yellow alkaline noodles prepared with different ingredients and distinguish them.

Cooking Quality

Cooked instant noodles should have a relatively strong bite with a firm, smooth surface and good mouthfeel (Hou, 2001). Cooking quality of instant noodles is influenced by several factors such as protein content, ash content, damaged starch, starch quality, thickness of noodle strands and frying conditions. Rehydration rate, cooking time and cooking loss are the measure of cooking quality and ease of preparation. Protein content and amylose content correlates positively and negative, respectively with the optimum cooking time of noodles (Park and Baik, 2004a). Okada (1971) observed that the ash content of flour had a positive correlation with weight and volume gain rates during cooking. Frying time affects the cooking time and rehydration rate while cooking instant noodles. Starch structure of noodles is maintained as a ramified three dimensional network that is interlinked by amylose based crystallites (Mestres et al., 1988). Amylose networks swell during boiling in water due to hydration of amorphous regions. Matsuo et al. (1986) reported that proteins act as an essential structural component in noodles during cooking causing noodle strands to integrate and maintain their form during cooking. The heating method, rate of heat transfer and cooking time are also important parameters that determine the cooking quality of an instant noodle. Cho et al. (2010) studied the application of a microwave oven for the preparation of instant noodles and found it to be advantageous as it enhanced the convenience in preparation of the instant noodle and reduced the cooking time.

Oil Uptake

Oil uptake in noodles can be explained by capillary action (Pinthus and Sam Saguy, 1994) or by oil replacement of removed water (Gamble et al., 1987). During noodle frying, many tiny holes are created as water is rapidly removed and replaced by oil on the surface of the noodles (Hou, 2001). The content and quality of the wheat protein is believed to play a role in oil absorption. Moss et al. (1987) reported that noodles made from high-protein wheat flour absorbed less oil than noodles made from low-protein flour. They proposed that the high oil absorption in low-protein flour noodle was due to the formation of coarse globules during steaming, allowing oil to penetrate easily through the noodle. Wheat flours with high-protein content and high SDS sedimentation volume or low proportion of salt soluble protein produce instant noodles with low levels of free lipids probably due to the formation of a smooth and compact noodle surface structure in the course of steaming process (Park and Baik, 2004b). Gazmuri and Bouchon (2009) showed that gluten has a predominant role in the structure, making the dough more elastic and less permeable to oil absorption. Starch amylose content also affects the development of bubbles on the surface of instant noodle strands. A strong inverse correlation between amylose content and oil content of instant noodles was reported using reconstituted flours (Park and Baik, 2004c). The high oil uptake by noodles during frying also increases production costs and adversely affects shelf-life (Moss et al., 1987; Rho et al., 1986). Protein content and protein quality were the major factors which correlated negatively with oil content of instant noodles (Park and Baik, 2004b). Starch properties, gel hardness, gumminess and chewiness as well as pasting properties were other important contributors. Starch gel hardness, gumminess and chewiness were positively correlated with oil content of instant noodles, while pasting properties were negatively correlated (Wu et al., 2006).

The oil content of instant noodles is an important quality index. NIR spectroscopy analysis has been used in determining the oil content of instant noodles (Chen, Fang, & Zhao, 2000; Chen & Qian, 1999). Chen et al. (2002) demonstrated improvement in predicting precision of oil content in instant noodles by using wavelet transforms to treat near-infrared spectroscopy.

RECENT TRENDS IN NUTRITIONAL IMPROVEMENT/ FORTIFICATION OF INSTANT NOODLES

Instant noodles are fortified either by the fortification of flour used to make noodles by addition of gluten, other flours such as soya, buckwheat (Van Hung et al., 2007), oats, barley and legumes flour or by fortifying the seasoning consumed along with the noodles. Micronutrients including vitamin A, B1, B2, niacin, folic acid, iron, and iodine can be added after considering their stability during processing and recommended daily values. Calcium carbonate and gluten are also added to improve the nutritional properties of instant noodles. Fortification of instant noodles with vitamin A, B1, B2, niacin, B6, folic acid, iron, and casein (milk protein) was initiated in 1994 in Indonesia. However, fortification is not mandated by government regulations. Currently, about 80% of instant noodles produced in countries like Phillipines are fortified voluntarily. In 1997, the FOSHU (Food specified for health use) approved a health claim for psyllium in instant noodles. Fortifying the seasoning rather than the flour has an advantage that the fortificants are not exposed to heat and moisture during noodle processing. In addition, the fortificants are better protected being packed in a sachet. Table 4 enlists some fortificants used to improve the nutritional properties of noodles.

It is relatively simple to add fortificants, but ensuring the stability of nutrients in seasoning mixture throughout the shelf life of instant noodles is a major concern. Thiamin stability affected by formulation, processing and storage has been reported by Bui and Small (Bui and Small, 2007b, d, 2008) in noodles and it was inferred that potential to use thiamin in noodles where alkaline salts are used is limited due to its instability at higher pH. Hau Fung Cheung et al. (2009; 2008) investigated folic acid stability in fortified instant noodles by use of capillary electrophoresis and reversed-phase high performance liquid chromatography and reported that it was stable during mixing, sheeting, steaming and frying of instant fried noodle. Bui and Small (2007a; 2007c) also evaluated the effectiveness of noodles as potential vehicles for fortification with folic acid. Differing patterns of retention was observed in different type of noodles with similar overall losses of slightly more than 40% for all types. Significant losses occurred for instant noodles during steaming and deep-frying of the noodle strands and during subsequent cooking in case of dried noodles. However, it was concluded that fortifying noodles provides an effective means for enhancing folate intake. Khetarpaul and Goyal (2007) reported that protein content and quality can be improved in noodles by incorporation of soy, sorghum, maize, and rice at 10% level without significantly affecting overall acceptability of the product. Chen et al. (2011) investigated the effect of particle size and addition level of wheat bran on quality of dry white Chinese noodles (DWCN) and reported that hardness, gumminess, chewiness and overall acceptability score of cooked noodles decreased while adhesiveness increased with higher bran content and bran particle size. It was also concluded that 5-10% bran can be satisfactorily incorporated to prepare fiber-rich DWCN. Substitution of 10% oat flour in noodle formulation gave satisfactory results in terms of overall acceptability of the product. Higher levels of oat flour substitution in noodles improved the protein, fat, ash and minerals, however, negatively affected the cooking quality and sensory properties (Aydin and Gocmen, 2011). Sudha et al. (2011) investigated that inclusion of defatted soy flour (DSF) and whey protein concentrate (WPC) in instant vermicelli not only enhanced their protein content and in vitro protein digestibility but also reduced the fat uptake in noodles.

Efforts are underway to improve the formulation, extend the shelf life and promote universal fortification of instant noodles. Accordingly, many researchers are exploring the potential of instant noodle fortification as an effective public health intervention and improve its nutritional properties while manufacturers voluntarily fortify their products.

Conclusions

Noodles are the staple food in Asian countries like China, Japan and Korea. Consequently, the locally preferred salted and alkaline noodles have been studied extensively by the researchers. Instant noodles are currently the most important convenience food preferred by consumers globally due to their excellent flavour, convenience and ease of preparation. Colour, texture, cooking quality and oil uptake largely influences the acceptability of the noodles. Wheat flour quality, ingredients and process parameters are considered important in determining the quality of noodles. Wheat flours with lower ash content, higher protein content, high SDS-sedimentation value, low starch gel strength, lower damaged starch are considered desirable for production of instant noodles. Appropriate selection of wheat varieties for instant noodles, knowledge of effects of processing variables and interaction of ingredients can be utilized to achieve a quality product. Newer technologies like confocal laser scanning microscopy (CLSM) and epifluorescence light microscopy (EFLM) can be successfully employed to understand the microstructure changes in dough and noodles while NIR spectroscopy can be used for other quality analysis purpose. Health concerns related to instant noodle consumption are often attributed to the higher amount of fat content in the product. Factors affecting the oil/fat uptake and strategies to reduce it can be identified and applied to remove such challenges and minimize the associated risks. Furthermore, fortification of instant noodles with essential micronutrients like vitamins and minerals, fiber and other flours which enhance their nutritional attributes can be targeted to ensure better nutrition to the people.

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Table I Ingredients used for manufacturing instant noodles (Hou, 2001; Hou and Kruk, 1998)

Ingredients	Amount (%)
Main Ingredients	
Wheat Four	100
Water	30-38
Salt (or Kansui)	1-3 (or 0.1-0.2)
Additional Ingredients	

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Starch	0-12
Edible oil	1-3
Vital wheat gluten	2
Polyphosphates	0.1-0.2
Stabilizers	0.1-0.5
Emulsifiers	0.1-0.5
Guar gum	0.1-0.2
Antioxidants and Preservatives	Minimum needed for technical effect
Colour	As needed

Table II Function of various additives used in instant noodles

Additives	Functional property	Examples	Reference
Stabilizers	Improves rehydration during cooking, modifies the texture and overall ‘‘mouth-feel” of finished product and decreases the fat uptake during frying	Guar gum, locust bean gum, alginates and CMC	(Yu and Ngadi, 2006)
Emulsifiers	Prevent starch retrogradation, improve texture and structure, and improve cooking quality	Glycerine fatty esters, sucrose fatty ester, lecithin	(Shiau, 2004)
Phosphates	Accelerate gluten bonding which improve noodles elasticity, flexibility, texture and chewing properties; facilitate the starch gelatinization during cooking allowing more water retention in the noodle and reduces water cloudiness while cooking	Sodium polyphoshate	(Hourant, 2004)
Enzymes	Increases break strength and firmness; reduces stickiness and cooking loss	Transglutaminase, lipases, oxidoreductase, and amylases	(Crosbie and Ross 2004)
Antioxidants	Inhibit or interfere with the chain reaction mechanisms that produce compounds responsible for rancidity	BHA, BHT, PG, TBHQ	(Fu, 2008)
Colorants	Provide the desirable yellow colour	β-carotene, tartrazine, vitamin B2, carotenoids and flavonoids	(Crosbie and Ross 2004)

Table III Evaluation of instant noodles (Hou and Kruk, 1998)

	Evaluation criteria
Mixing	Optimal water absorption, small and uniform dough particle sizes with no big lumps
Sheeting	Smooth, non-streaky surface free of specks and easy to sheet
Slitting	Clean cut with sharp edges and correct noodle size
Waving	Uniform and continuous waves
Steaming	High degree of starch gelatinization, not sticky and good wave integrity
Frying	Uniform noodle colour, good shape, not oily and characteristic fried noodle aroma
Cooking	Short cooking time, low cooking loss, good texture tolerance to overcooking
Colour	Bright yellow colour
Texture	Optimum bite, firm, chewy, smooth surface, good mouthfeel and stable texture in hot water

Table IV Examples of some fortificants used in noodles

Fortificants	Nutritional significance	Reference
Thiamin	Improved vitamin B1 intake	(Bui and Small, 2007b, d, 2008)
Folic acid	Increase in folic acid intake prevents many ill health effect caused by its deficiency	(Hau Fung Cheung et al., 2009; Hau Fung Cheung et al., 2008)
Banana flour and oat β- glucan	Enhanced total dietary fibre content, antioxidant properties, lowered the Glycemic index, carbohydrate digestibility rate, and increased essential minerals (magnesium, calcium, potassium and phosphorus) and proximate components, with the exception of crude fat	(Choo and Aziz, 2010)
Oat bran	Rich in β -glucan, a soluble fiber	(Reungmaneepaitoon et al., 2006)
Lupin flour	High in protein and dietary fiber contents	(Jayasena et al., 2010)

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Sweet potato flour and defatted soy flour	Source of β-carotene and protein respectively; increase in total dietary fiber, mineral/ash, and decrease in fat/carbohydrates	(Collins and Pangloli, 1997)
Hull-less barley flour	Higher total dietary fiber content (including β-glucans, arabinoxylans, cellulose, fructans and galactomannans)	(Hatcher et al., 2005; Izydorczyk et al., 2005; Lagassé et al., 2006)
Nutrim (soluble fiber from barley and oats)	Good source of soluble dietary fiber	(Mohamed et al., 2005)
Zinc and iron	Nutritional source of iron and zinc	(Romana et al., 2002)
Wheat bran	Source of dietary fiber	(Chen et al., 2011)
Defatted wheat germ	Improves the amino acid and mineral content	(Ge et al., 2001)
Coconut flour (defatted)	Good source of fiber and protein	(Gunathilake and Abeyrathne, 2008)

Figure Legends

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Figure 1 Consumption of instant noodles in world in recent years (WINA, 2011)

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Figure 2 Consumption of instant noodles in different countries (data figures represents 100 million packets; plotted using data from WINA (2011))

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Figure 3 Consumption of instant noodles in India (WINA, 2011)

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Figure 4 Processing and classification of instant noodles (Kim, 1996b)

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