Proceedings of the Pakistan Academy of Sciences:
B. Life and Environmental Sciences 53 (3): 215–238 (2016)

ISSN: 2518-4261 (print), ISSN 2518-427X (online)

Pakistan Academy of Sciences

Research Article

Rice Noodles: Materials, Processing and Quality Evaluation

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Abstract: Asian peoples consume noodles as a staple food since ancient time. It is convenient, easy to cook, delicious and nutritionally rich product and is now gaining great appraisal outside Asia also. Generally, rice noodles are prepared from flour, salt, water and various optional ingredients. Rice flour is kneaded in the presence of water and salt to form dough and is then sheeted, compounded, steamed and cut to form a noodle strands. The noodle strands can be further processed (dried, fried, boiled and frozen) to develop various types of noodles based on consumer preferences. This review article focus on different ingredients and their functionality as well as the processes involved in transforming raw material to finished product. Protein, ash, dough strength and amylose concentration are very crucial regarding noodle quality. Variation in compositions affects the cooking, functional and eating properties of noodles. Due to the absence of gluten, rice noodles have less cohesive and extensive texture. Steaming gelatinizes rice starches up to some extent, which aids in the partial compensation of gluten role in rice based noodles. The trend towards gluten free noodle is due to their health beneficial effect as they help in lowering the risk of allergic reactions and celiac diseases, as well as induce lower glycemic index for patients suffering from diabetics. High quality noodle must be bright in color, have an adequate shelf life without oxidative rancidity or microbial spoilage, and have good textural and cooking properties.

Keywords: Rice noodle; raw materials; processing; quality characteristics

1. INTRODUCTION

1.1 History and Classification of Noodles

Since ancient times, noodles in various formulations and shapes have been used as staple food in many parts of Asia [1-2]. This is evident from the literature that Chinese were the first to introduce noodles to the world, rather than Arabs or Italians. Noodles were very popular during the era of Han dynasty (25-220 AD) in China. During the early 20th century, alkaline noodles were introduced in Yokahama city of Japan by Chinese immigrants. Later on, Japanese develop instant noodles by a different process, which became the most popular food not only in Asia but all over the world [1]. Both China and Japan did a lot of innovation and employed modern technology in noodle processing that substantially increased the consumption and acceptance of noodles outside Asia also. Noodles experienced substantial evolution and migration in spite of its origin due to the increase in globalization [1, 3].

Noodles are classified into different types on the basis of raw material, processing methods, salt composition, size of noodle strand and form of noodles in the marketplace. Wheat noodles, rice noodles, starch noodles, mung-bean starch noodles and buckwheat noodles are few examples of noodle types which are available in the market nowadays. Noodles are classified into hand-made standard or flat noodles (teuchiudon or teuchihira-men) and thin hand-made noodles (tenobe so-men) based on manufacturing involved. Additionally,

Received, April 2016; Accepted, June 2016
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these are also classified on the basis of form of product in the marketplace i.e. instant noodles, boiled noodles (yude-men), dried noodles, (kan-men), steamed noodles (mushi-men), frozen boiled noodles, instant cup noodles, and machine made noodles [1]. Noodles are also classified as Japanese type wheat noodles, buck wheat noodles (Soba), Chinese type wheat noodles, Naengmyon noodles (Korean type noodles), starch noodles, rice noodles and pasta based on the raw materials and other ingredients used [3, 4]. Rice noodles are prepared by gelatinization of dough using cold extrusion process [5].

1.2 Rice Noodles

Noodles are safe and nutritious product that conforms to the set food standards of various countries. With the increase in Asia pacific economy, the demand for quality noodle products among consumer gets higher [1]. Rice noodles are the most consumed form of rice product next to cooked rice grain in Asia [6]. Noodles may either be served by frying and mixing with vegetables and meats or served as a soup noodle by boiling in a broth. Rice protein lack gluten; hence lack the functionality of continuous visco-elastic dough. Rice flour is therefore pre-gelatinized in order to act as binder for the remaining flour. The extent of pre-gelatinization plays a vital role in providing desirable texture to the noodle strands. The level of gelatinization is maintained adequately to develop the desired binding power during the process of extrusion; though too much gelatinization may create handling problems [6]. Rice noodles are commonly prepared by two main methods; sheeting of dough to develop flat noodles and extruding to develop vermicelli. The raw materials for rice based noodles are usually evaluated by determining their functionalities; processes involved and desired end product [1].

Generally, rice noodles are made from flour containing high amylose concentration (> 22%), which contributes to the gel network. It provides firm structure and desirable properties to noodle [5-6]. There is significant association found between amylose and acceptability of rice noodles [7]. The wide variation in physical and chemical properties of rice flour greatly influences the textural quality of rice noodles. Additionally, rice noodles properties are also influenced by paste viscosities, swelling power (SP) and gel texture of rice starch. The high amylose concentration in rice flour gives noodle with bright color and low bulk density because of their educed swelling power [8-10].The chemical composition i.e. protein, fat, carbohydrate and ash concentration of rice noodles were found to be 7.20%, 0.84%,91.7% and 0.24%, respectively [11]. The texture of rice noodles is less cohesive and extensive due to the absence of gluten. The textural, cooking and sensory properties depend upon the pasting and physicochemical attributes of rice flour obtained from different rice varieties [5, 9, 12]. Flour particle size can also influences the properties of noodles [9, 13]. However, noodles made from flour having smaller particle size showed better textural properties [13]. Similarly, the smaller particle size had highest water absorption index, hot paste viscosity, peak viscosity, and breakdown, final or cold paste viscosity and gel hardness, but the lowest gelatinization temperature [5, 13]. However, fat concentration did not significantly influence the properties of noodles [5, 10, 13].

Rice vermicelli is prepared from flour having high amylose concentration, which is obtained by steeping followed by wet milling. The flour is filtered, pulverized and molded into balls that are pre-cooked in boiling water for 20 minutes or steamed to facilitate surface gelatinization. The partially cooked balls are kneaded, which causes uniform distribution of the gelatinized starch all over the dough which performs a binding role. The dough is then passed through the extruder or noodle making machine to make noodle strands. The noodle strands are then put in boiling water and taken out when cooked adequately. Immediately, the cooked noodles are cooled by transferring into a cold water container. The noodles are then allowed to dry by placing them in racks. On the other hands, the noodles can also be subjected to steaming process for a time period of 10-15 minutes, by directly placing them in racks, followed by tap water washing, and drying. Dry milling is preferred to wet milling for making rice noodles in Japan. The dry milled flour is mixed with water and heated for about one minute at 100 ^{o}C to cause partial gelatinization of starch and then kneaded by the help of screw kneader or by hands [1, 13].

Flat or sheeted fresh rice noodles are famous in many areas of Southeast Asia, southern China and Japan. The dough is placed in a rotating heated drum to form sheets. The sheets are then placed in a steamer that causes partial gelatinization of starch. About 1 mm thick sheets are passed through the cutting rolls to form noodle strands. The noodles are then served either as fresh rice noodles or can be dried before sale. The process involved in the preparation of Japanese rice noodles comprises of the following steps; washing milled rice, pulverizing, steaming, kneading and sheeting. The final thickness of the noodle sheet is maintained at about 1-2 mm before cutting [1, 9, 14].

2. RAW MATERIALS FOR RICE NOODLES

The basic ingredients used to develop rice based noodles include flour and water, along with additional ingredients i.e. salt, oil to improve the quality of final product. Raw materials are judged by determining their physicochemical properties and processing parameters. It is important that raw materials possess appropriate functional and processing properties in order to develop a quality product [1, 15].

2.1 Rice Flour

Rice flour is obtained from fine milling of rice kernels. Rice flour may be made from either brown rice or white rice [16]. It is energetic and basic food consumed on a regular basis and has a very high digestibility value. Rice flour comprised of about 0.4–0.8% fat, 7% protein and 78% carbohydrates[17]and provide substantial amount of B vitamins; thiamin, niacin and riboflavin [18]. Different type of products are made from rice flour, such as bread, noodles, cakes, and other conventional products developed in the homes or in the industries, across the world [1, 10]. Different types of noodles consumed in the Asia-Pacific region. Each noodle is preferred and consumed in different culture within different region of Asia. Hence, it is not easy to discuss flour specifications or quality, without recognizing the type of noodle, method of production, production environment, existing facility and regional preferences [1].

The flour physicochemical properties would facilitate the understanding of its possible uses and applications [11]. Brown rice variety had the highest protein concentration (8.16%) and lowest fat concentration (0.07%). However, white rice variety has high amylose concentration (27.71%), while brown rice variety has low amylose concentration (3.36%). On the other hand, white rice had 25.0% amylose, 8.0% protein and 2.2% fat concentration [19].Rice flour is categorized according to the presence of amylose concentration, as either high amylose (25-33%), intermediate amylose (20-25%), low amylose (12-20%), very low amylose (2-12%) and waxy (1-2%). On the basis of cooking properties, rice is categorized into two groups; waxy and non-waxy rice. Waxy rice is mostly composed of amylopectin and produces chewy and sticky structure; whereas non-waxy rice contains 10-20% amylose and produce firm noodle [20].

The quality attributes of rice grains are appearance, cooking and eating properties as well as nutritional value [21]. Rice varieties containing high amylose concentration, high gel consistency and low gelatinization temperature are appropriate for making rice noodles [7]. Rice flour having intermediate amylose concentration produce soft texture noodles. Such noodles lead to high solid loss in cooking water. Noodle made from very low amylose concentration flour lead to very poorly textured noodles and is therefore not used in preparing noodles [22-23]. The granule size of rice starches may vary from 3 to 8 μm and is much smaller from granules obtained from other starch sources. The use of larger granule size (> 20 μm) for noodles making showed higher processing ability and quality attributes [24]. Rice flour starches exhibited weaker resistance toward shear forces and do not form strong gel. It also loses thickening power and viscosity significantly during cooking process. The gelling property of rice starch is dependent upon rice varieties, amylopectin and amylose concentration, as well as the duration of the ageing [25]. Physical modification of flour such as addition of water and heat treatment improves the eating and cooking properties of rice noodles [7].

The adaptation of proper milling process is very important to obtain flour of desired properties i.e. bright color, fine particles, low ash concentration and damaged starches. Every type of noodles has their own specific protein range. The milling procedure must be adopted in such a way as to ensure proper separation of endosperm and bran, including tempering as well as break release adjustment in the mill [26]. Usually, flour containing high protein concentration is required to develop dried noodles, while boiled or fresh noodles are made from flour containing lower protein concentration. However, high level of protein in dried noodles helps to keep the noodle texture during drying. Protein concentration plays vital role in the preparation of instant noodles, because fat uptake decreases as the protein concentration increase during the frying process [27-28]. The natural color pigments in flour are destroyed by bleaching. Noodle darkening increases with higher extraction rate of flour. The high bran level resulted in dark color noodles due to the greater level of polyphenol oxidases in the bran layer. Low ash concentrations and low extraction rate are mostly preferred to develop high quality noodles with bright and clean appearance [1].

On the other hand, thermal properties such as gelatinization, pasting and retrogradation impart significant role in product development. It controls the rheological properties and determines the quality of starch based products [29]. Gelatinization refers to the disruption of molecular order within the starch granule, thereby leading to irreversible changes in properties i.e. loss of birefringence, granular swelling, loss of crystallinity and starch solubilization. The gelatinization process is governed by the concentration of starches, types of granule and amylose and amylopectin concentration. While retrogradation is the reassociation of starch chain into an ordered structure after starch solutions are cooled [30]. Zhou et al.[31]found no significant difference in onset temperature (T_o), while significant difference was noted in peak temperature (T_p), gelatinization enthalpy (ΔH) and conclusion temperature (T_c) in flour obtained from three different rice varieties, which were stored at 4°C and 37 °C for 6 months. Hormdok and Noomhorm [9] found that rice starch had 67.7, 73.49, 78.75 ^{o}C and 13.21 j/g in case of T_o, T_p, T_c and (ΔH), respectively. Bao et al [32] also observed similar results regarding rice starch. They concluded that gelatinization temperature is a critical step, as it is an indicator of processing and cooking quality. Gelatinization leads to collapse of double helical structure and crystallinity, which resulted in crystals melting at different temperature to form suspensions of starch mixtures. The variation in morphology and rigidity of starch granule causes differences in gelatinization peaks of waxy and indica starch. Amylose and amylopectin concentration also affect the gelatinization peak [30]. Tan et al [33] reviewed that long chain amylopectin might also be a factor to higher gelatinization temperature of starches. Therefore, it can be concluded that starch thermal properties are influenced by various factors like, variety, starch source, morphology of granules, amylose, amylopectin concentration etc. Flours containing high percent crystallinity and amylose concentration exhibited higher gelatinization parameters due to the rigid amorphous regions of starch granule by the association of amylose chains. This might increase the stability of amorphous region, thereby leading to higher energy input for gelatinization process [34].

Starch gel is defined as a continuous network of solid-liquid phases in which liquid is dispersed in the solid phase [35]. Hydrogen bond is formed between amylose molecules as well as with amylopectin branches of swollen granules. Morphology of starch gels and its strength is effected by different factors i.e. starch sources, cultivar or variety of each source, granule size and shape, moisture concentration, ratio of amylose to amylopectin, gelatinization time and temperature and pH [9, 36-38]. Comparatively, the gelling strength of aged rice flour is superior to flour obtained from freshly harvested rice grains [39]. Hormdok and Noomhorm [9] also observed that ageing of rice flour had increased the gel strength significantly, as evident from the observed values of 27.38 (flour from freshly harvested grains) and 33.13 g (aged rice flour). Huang et al.[40] made mixed gel from two rice varieties (Japonica and Indica starch), hydrocolloids (carrageenan and gellan), deionized water and $CaCl_2$. They observed the influence of rice starch, hydrocolloids and its concentration on the quality of gel via texture profile analysis. It was found that the texture of the gel depends on rice variety, hydrocolloids and its concentration. Addition of 0.2% (w/w) carraggnan to the Indica rice starch improved the texture of rice gel. While, addition of 0.3% (w/w) gellan to the Indica rice starch enhanced the adhesiveness/ hardness ratio.

Likewise, pasting is an important functional property, which occurs after gelatinization in starch dissolution. It is an important index for evaluating the starch properties of rice [39]. It consists of swelling of starch granules, leaching of molecular components from granules and finally total rupture of granules. Several parameters can be acquired from the pasting curve, which manifest the extent of disintegration and beginning of retrogradation [41]. However, starches obtained from tubers and roots showed weak intra-granular bonding, lower gelatinization temperature, rapid and uniform granular swelling, paste clarity and high viscosity compared to cereal starches [41]. The peak viscosity (PV), trough (T), break down (BD), final viscosity (FV), set back (SB) and pasting temperature of rice flour were 253.17, 191.29, 61.88, 351.38, 160.08 RVU and 76.38 °C, respectively [9].The pasting properties of rice flour from aged (paddy and milled) rice and fresh rice from two rice varieties stored at different temperature conditions for a storage period of 10 months is shown in table 1. The SB and FV values were increased with the increase of storage temperature and time. Moreover, the rise in SB values showed a higher degree of retrogradation due to the increase in rice firmness [42]. The rice flour obtained from milled rice and stored paddy was firmer compared to flour procured from fresh rice; hence stored rice gave less sticky texture [39]. Ageing of rice and amylose concentration significantly influenced the pasting properties of rice [43]. Kanlayakritand Maweang [44] studied the pasting properties of rice flour obtained from stored paddy and freshly milled rice under different

Table 1. Comparison of pasting properties of rice flour from fresh rice and aged (paddy and milled) rice from two rice varieties stored at cold room, room temperature and warehouse for 10 months [44].

Rice sample	Storage condition	Peak Viscosity (RVU)*	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)
Kalasin11	Fresh rice	247.64 ± 3.95^{f}	131.66± 1.80^{f}	115.98 ± 5.75^{e}	267.63± 3.95^{g}	135.97 ± 5.75^{d}
	Room Temperature[1]	199.60 ± 3.93^{j}	151.62± 2.26^{bc}	47.99 ± 1.68^{i}	334.33± 1.97^{b}	182.72 ± 0.29^{b}
Paddy	Cold Room[2]	225.66 ± 2.64^{h}	143.45± 1.17^{de}	82.21 ± 3.81^{g}	282.81± 3.13^{e}	139.36 ± 1.96^{d}
	Warehouse[3]	186.99 ± 6.26^{k}	154.54± 3.81^{ab}	32.46 ± 10.08^{j}	356.49± 3.15^{a}	201.96 ± 0.66^{a}
	Room Temperature[1]	211.79 ± 3.50^{i}	147.27± 4.26^{cd}	64.52 ± 7.76^{h}	322.48± 3.17^{c}	175.22 ± 1.10^{c}
Milled	Cold Room[2]	239.51 ± 2.50^{g}	138.63± 2.53^{e}	100.88 ± 0.03^{f}	276.50± 0.93^{f}	137.87 ± 1.61^{d}
	Warehouse[3]	201.94 ± 3.52^{j}	152.58± 2.60^{bc}	49.36 ± 6.12^{i}	331.47± 1.66^{b}	178.89 ± 4.26^{bc}
KDML105	Fresh Rice	331.62 ± 4.58^{a}	126.34± 4.06^{f}	205.28 ± 0.52^{a}	219.68± 1.21^{j}	3.34 ± 2.85^{g}
	Room Temperature[1]	288.50 ± 3.92^{d}	155.86± 4.77^{ab}	132.64 ± 0.84	265.44± 1.02^{g}	109.58 ± 3.75^{f}
Paddy	Cold Room[2]	303.34 ± 2.95^{c}	141.66± 2.02^{de}	161.68 ± 4.97^{c}	234.38± 2.09^{i}	92.72 ± 4.11^{g}
	Warehouse[3]	276.57 ± 3.08^{e}	159.57± 1.48^{a}	117.00 ± 4.55^{e}	293.51± 2.41^{d}	133.94 ± 3.89^{d}
	Room Temperature[1]	301.40 ± 2.64^{c}	142.04± 1.29^{de}	159.37 ± 3.94^{c}	251.76± 1.61^{h}	109.72 ± 0.31^{f}
Milled	Cold Room[2]	322.90 ± 3.00^{b}	139.58± 0.90^{e}	183.33 ± 3.90^{b}	231.39± 1.06^{i}	91.82 ± 0.16^{g}
	Warehouse[3]	287.55 ± 1.94^{d}	151.08± 1.08^{bc}	136.47 ± 3.03^{d}	274.38± 2.09^{f}	123.30 ± 3.17^{e}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05).
[1]Room temperature (30±5°C),
[2]Cold Rooms (20±5°C),
[3] Warehouses (40±5°C).
*RVU = Rapid Visco-analyzer Unit

storage conditions. Amylose concentration significantly influenced the RVA pasting properties of fresh rice flour. On the other hand, stored paddy showed significant difference in pasting properties during the storage period. Peak viscosity (PV), trough (T), final viscosity (FV) and setback (SB) of KDML105 rice flour were lower than Kalasin11 rice flour that were obtained from milled rice and stored paddy, respectively. Furthermore, it was observed that the changes in pasting properties of milled rice were lower than stored paddy. It was noticed that the paste viscosity decreased as the ageing process proceed [44]. The structure of rice granules became more organized during storage. Although, the surface of granules characterizes the major barrier to hydration, consequently, pasting may be affected by the presence, nature and orientation of surface proteins and lipids. Protein is basically composed of amino acids and is hydrophilic in nature. Any changes in the granules during storage and processing could alter their hydrophilicity, which would influence the hydration and swelling of granules, thereby influencing the pasting properties of rice flour [31, 42-43, 45]. Storage of rice at cold temperature stopped alterations in the pasting properties [31, 46].

Techawipharat et al. [47] observed that waxy rice starch had much lower pasting properties than normal rice starch. This is due to the lower amylose concentration (< %) in waxy rice starch. Granular interaction and amylose concentration significantly affected the starch pasting properties. Similarly, storage temperature and duration also influenced the pasting properties of rice flour [31, 43, 45-46]. Inglett et al.[48] investigated the pasting properties of blends of rice and wheat flours. It was observed that the pasting properties of wheat flour increased with the increase in the concentration of rice flour in the blends. Nura et al. [13] evaluated the pasting properties of rice flours with different particle sizes. It was found that variation in particle size influenced the pasting properties as shown in table 2. Pasting temperature of rice flour samples was decreased significantly with the reduction in particle size. This could be attributed to the smaller particle size, which provides greater surface area for rapid hydration. The starch granules swell quickly leading to gelatinization of starch at lower temperature. Rice flour with smaller particle size attained the onset gelatinization temperature earlier. Peak viscosity (PV) shows the highest viscosity attained by starch under given conditions during the gelatinization process (Shuey and Tipples, 1994). Rise in PV indicates the ability of starch granules to swell up to the extent before physical breakdown occurs [49]. However, set back (SB) was comparatively higher in all the flour samples evaluated. This might be due to leaching of amylose in starch gel that caused quick retrogradation and gave harder texture after cooling [13]. The SB shows the retrogradation tendency and is determined by the difference between PV and HPV [5]. On the other hand, hot paste viscosity (HPV) is affected by the formation of amylose-lipid complex, granule swelling, amylose exudation, and competition between remaining granules and exuded amylose for free water [50].

Table 2. Pasting properties of rice flours with different particle sizes [13].

Particle Size (μm)	Peak Viscosity (RVU)*	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Pasting Temperature (°C)
140	221.21±1.04^{d}	150.67±0.50^{b}	70.54±1.54^{a}	317.38±4.88^{c}	96.17±5.92^{a}	82.37±0.30^{c}
125	226.58±2.76^{c}	154.78±4.09^{ab}	71.81±2.68^{a}	321.86b±4.44^{c}	95.28±2.51^{a}	81.52±0.06^{b}
100	229.08±1.59^{bc}	156.53±2.87^{ab}	72.56±4.44^{a}	326.14±1.98^{ab}	97.06±3.54^{a}	81.40±0.00^{b}
80	232.17±1.26^{b}	159.17±8.03^{a}	73.00±9.27^{b}	327.97±4.71^{ab}	95.81±5.97^{a}	80.97±0.51^{a}
≤63	237.36±1.28^{a}	160.56±2.65^{a}	76.81±3.62^{a}	332.53±5.76^{a}	95.17±6.57^{a}	80.81±0.15^{a}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)
*RVU =Rapid Visco-analyzer Unit
Values are Means ± SD of triplicate determinations

2.2 Water

Water is considered to be the second key raw material used in noodle making after flour. The proportion of water used in noodle making should be optimum (30–35%) in order to optimally hydrate the flour for making dough of proper consistency [2]. Addition of excess water results in soggy dough, while too little water creates difficulty in dough formation and sheeting [51]. It furnishes the required medium for all the biochemical and physicochemical reactions in transforming the raw components into finished products. It can dissolve the water soluble components prior to mixing. The water used for making noodle should meet the sanitary requirements to produce high quality products [1, 2, 52].

Water varies in characteristics depending on its origin. Surface water usually contains higher level of chemical, microbial and organic contaminants compared to ground water. However ground water is relatively richer in dissolved inorganic substances. Water are characterized as either hard, soft, saline or alkaline depending upon the amount and types of mineral salts available in natural water, which has a pH value between 5.8 and 8.6 [1]. All these types of water affect flour hydration, starch gelatinization, sheeting process and texture of noodles. Hard water is not used generally because it reduces the water retention capacity of the flour. The available ions in hard water substantially affect the gelatinization of starches in subsequent steaming or boiling process. While, very soft water yields sticky and soft dough sheets. Low to medium hard water is considered desirable for noodle processing. The high alkaline water is due to the presence of magnesium and calcium ions. After boiling, the pH of alkaline water rises to 9 due to the decomposition of bicarbonates upon heating to form the subsequent carbonates. Therefore, alkaline water is not used in the processing of noodles, particularly for manufacturing boiled noodles. Organic acids i.e. acetic, citric, lactic, malic or citric acids are added sometimes to adjust the pH of water for the preparation of boiled noodles [1-2, 9, 52].

2.3 Salt

Salt is another basic ingredient which is used in noodle preparation, which is added up to 1-3% of flour weight. However, about 8% of salt could be used in the formulation for processing of boiled Udon and hand-made noodles. Salt play three major role in noodle processing. The most important function is its tightening and strengthening role in dough gluten that is attributed to its inhibitory effect on proteolytic enzymes. While, other evidences shows a direct relationship between protein and salt. It substantially enhances dough sheeting properties, particularly at a higher water absorption index. The next important role that salt contribute is the improvement of texture and flavor. In addition of providing salty taste, it also acts as a flavor enhancer in many other foods. It imparts fullness to the "mouth-feel" and masking possible off-taste. Salt significantly reduce the cooking duration and provide elastic and softer texture. The third important role of salt is its inhibitory effect on microbes and various enzymes. Salt retard the spoilage and oxidative reactions at high humidity and temperature, thereby prolonging the shelf life of products. Higher concentration of salt in noodle formulation also reduces the drying rate [1].

However, by considering the consumer preference, alkaline salt are used alone or in combination with various salts. Potassium and sodium carbonates are the most commonly used alkaline salts. While, other alkaline reagents i.e. bicarbonates and sodium hydroxide are also added occasionally. Alkaline salts are added at a rate of 0.5 to 1.5% in noodles having strong alkaline flavor, while added at a rate of 0.1 to 0.3% in few noodle types for the purpose of improving their quality [1]. The yellowish color of alkaline noodles is provided by the natural pigments such as flavonoid present in flour, which behave as color in acidic medium, while turn to yellow in alkaline medium. A greenish-yellow color is given to the noodles by the incorporation of potassium carbonate that also have less reflectance as compared to noodles prepared by the addition of sodium carbonate. However, sodium hydroxide gives more yellow and brighter noodles. Addition of alkali gives inelastic dough that can hardly be compressed during sheeting. It provides a firm texture compared to noodles made from only salt [1, 28].

2.4 Oil

After the process of steaming and molding, instant noodles are mostly fried in oil. Oil used in noodle processing must be about 20 percent of the noodle weight. Among the different types of oil available in the market, palm oil is extensively used in Asia, due to its availability, heat stability, better frying performance and cost effectiveness [1]. Similarly, partially hydrogenated canola and soybean oil is used to fry instant noodles. The degree and conditions of the hydrogenation must be balanced to provide desired properties. The oil should be selected based on the consumer preferences, as the oil compositions can significantly influence the flavor of final product. Usually, the oil deteriorates during cooking due to complex series of chemical reactions [14]. Thermal oxidation causes decompositions of non-volatile and volatile components. These decomposed products build up to a greater extent with extended heating and results in deterioration and sensory failures of the finished products. Hence, stability of oil during heating process is a great concern in the selection of oil. Furthermore, non-refined oils should not be used for frying purpose, as it can cause undesirable changes in flavor and color of the noodles. The specification mostly considered in selecting frying oils include flavor, color, peroxide numbers, free fatty acids, smoke point, melting point and iodine number [1, 14].

2.5 Improvers

Hydrocolloids and polyphosphates are commonly used to improve the overall quality of noodles. The use of polyphosphate increases the gelatinization of starch and water retention ability of the noodles during cooking. It also modifies the properties of dough and retards formation of off-color in raw noodles by acting as chelating agents. It is mostly added at 0.1% in the flour [1]. Similarly, hydrocolloids i.e. guar gums are extensively used in the processing of rice noodles. They are hydrophilic in nature and increase the water binding capacity of the flour. Gums added at a level of 0.2 to 0.5% of the flour weight enhanced the water absorption capacity and altered the texture properties and overall mouth-feel of the end product. Usually, gums are added in the salt solution prior to mixing of dough. Synthetic and natural colors can be added to different types of noodles (alkaline noodles, tea noodles and vegetable noodles) in order to improve their natural color [1, 22].

2.6 Preservatives

The shelf life of raw noodle could be prolonged by inhibiting growth of micro-organisms with the inclusion of alcohol in the formulation [42, 44]. Usually, the noodles are immersed in dilute solution of organic acids prior to packaging. Steamed and deep-fried instant noodles have comparatively higher fat concentration (> 15%), hence there is greater chances of oxidative rancidity. The use of antioxidants such as butylated hydroxy-anisole (BHA), tertiary-butylhydroquinone (TBHQ), butylated hydroxytoluene (BHT) and propyl gallate are commonly used to avoid oxidative rancidity. Among these, TBHQ greatly reduced the oxidation process [1, 31].

3. PROCESSING OF NOODLE

Regardless of the great variance in size, shape and formulation; the noodle making process is constant for all types. Generally, it consists of dough mixing, dough sheeting, compounding of dough sheets, and reduction in sheet thickness and formation of noodle strands. The noodles can be processed further in various ways after cutting. Afterward, the noodle strands can be distributed directly to the market or can be marketed as a raw noodles or can be dried, boiled, fried, frozen, steamed or combination of these processes can be used to develop large array noodle types[1].On the other hand, Hormdok and Noomhorm [9]made noodles by a different method. Instead of dough, slurry was prepared by mixing rice flour with water to a concentration of 40g/ 100g. The slurry was allowed to equilibrate for 60 minutes and poured to a stainless plate of 1 mm thickness to form a sheet. It was then steamed for 4 minutes and then allowed to cool at ambient temperature. The sheets were then cut into a strips of 3 mm and dried to 10-12% moisture level at a temperature of 40 °C. Rice noodles are mostly prepared by these two aforementioned methods.

3.1 Mixing

Mixing is the initial process in the formation of noodles. Water is added to flour in a container and other ingredients are also mixed. The ration of flour to water must be appropriate in order to make dough of optimum consistency. Mixing resulted in a uniform distribution of ingredients and also even hydration of flour. In the noodle making industry, two types of mixers are mostly used: the vertical mixer and the horizontal mixer. Generally, the mixers work at a speed of 70 to 100 rpm for 10-20 minutes and provide proper mixing and some kneading actions. However, vertical mixer is usually used on a large scale continuous product of noodles. The blades of vertical mixers have a large surface area that aid in the distribution of water evenly throughout the flour during the initial stage of mixing. It also provides a certain extent of kneading action after sufficient hydration of the flour. On the other hand, the horizontal mixer has single shaft or double shafts. The double shaft horizontal type mixer has shown best result in the mixing of dough. The blades of the shaft move in opposite direction, so that the dough crumbs move both horizontally and vertically during mixing [1].

Different types of mixers are also developed in the industry for performing noodle mixing i.e. low speed super mixer, continuous high speed mixer and the vacuum mixer. Low speed super mixer is used to mix dough with higher water absorption capacity. It is considered a copy of hand mixer and performs mixing at a speed of less than 10 rpm to minimize damage to the starch and protein matrix [1]. While the continuous high speed mixer is used to mix water and flour evenly in a very quick time. Water is added to the flour, which is rotated at a speed of 1500 rpm. High speed mixing leads to the formation of greater surface area for maximum hydration of water. Nowadays, vacuum mixer is used extensively in noodle industry. The vacuum mixing let addition of extra water to the flour without effecting processing efficiency [1, 5, 50].

The process of mixing is affected by flour quality, the addition of certain components, the volume of water added, the humidity and temperature of the processing environment. The water hydration correlates positively with protein concentration and can form dough crumbs of large size, consequently need less time for mixing [5, 34]. The greater level of damaged starch granules resulted from the milling of flour can also contribute to the increased water absorption capacity [50]. The concentration of water should be optimized in order to develop dough with good processing characteristics [5]. The ingredients such as salt and alkaline salt can also help flour hydration during mixing. Mixing process conducted at lower temperature slow down the hydration of flour. It is also not desirable to perform mixing process at a temperature of greater than 35^{o}C, as enzymatic activity and protein degradation can occur at such higher temperature. The optimum temperature is for making proper noodle dough is 25-30 ^{o}C [50]. Afterward, the dough is rested for some time that allows uniform hydration of flour particles and allows distribution of water to the dough mixture. The crumbly dough is agitated at a speed of 5-8 rpm for 10 to 20 minutes during the resting stage that avoid development of large dough crumbs and also facilitate dough feeding during the sheeting process [1, 5, 34, 50].

3.2 Steaming

The process of steaming is carried out in manufacturing rice noodle. During streaming, starch gelatinization and protein denaturation takes place in wet raw noodles. The cooking of noodles depends upon the original water, temperature and pressure of the steam and the time the product is exposed to steaming process [5]. Noodles steamed with hot water spraying speed up the starch gelatinization process and are stopped by washing with cold water. The dough must have high water absorption capacity and the steam must be highly saturated in order to develop quality steamed noodle. The steaming process is critical for noodle cooking. Under-steamed noodles are hard inside and causes problem in subsequent processing such as stir-frying prior to serving. While, over-steamed noodles are sticky and soft. For stir-frying the appropriate level of moisture must be about 59–61% in steamed noodles [1, 5].

Fari et al. [5] prepared noodle from 1 kg rice flour, which was mixed in a Hobart mixer to form dough. The dough was steamed for 30 minutes in a kitchen steamer. Then the dough was kneaded in order to distribute the partially gelatinized starch. Afterward, the dough was extruded in a pasta machine, fitted with a die having a pore size of 0.1cm. The noodle strands were steamed for 15 minutes and placed in an electric dryer at 40 ˚C for 4 hours. Detchewaet al. [53] also steamed the rice dough in a steam cooker for 30 minutes. After streaming, the rice dough was kneaded and extruded via a spaghetti die in a laboratory scale extruder. The rice spaghetti was dried till the attainment of 10% moisture concentration in tray drier. The steaming process is an important step in the production of instant noodles and rice noodles. Higher gelatinized starch is needed for the manufacturing of air-dried instant noodles. The steaming process takes less time in case of deep-fried noodles compared to hot air-dried noodles. Excessive starch swelling must be avoided during the steaming process, as it can cause many processing problems [1, 14, 55].

3.3 Sheeting

Since adequate hydration of flour particles are done after mixing and resting of dough. Starch gelatinization in rice based noodles takes place during the sheeting process. The uniform development of protein matrix with sufficient extensibility and elasticity is vital to obtain better processing and eating properties of the final product [1, 56]. The neighboring endosperms mix together to form continuous protein matrix during compression. Sheeting of noodle dough is proposed to obtain smooth sheets of dough with proper thickness as well as uniform and continuous gluten matrix and gelatinized starches distributed throughout the dough sheet [50]. The crumbly dough is conveyed to a hopper or sheeting rolls, and passed through the sheeting rolls to develop continuous dough sheets. After compression, the dough sheets are usually of non-uniform texture with rough surface. Two sheets of dough are then folded before the next pass. The combined sheets are then usually rested for few minutes to several hours. The maturing of dough at this stage helps the following sheet reduction process and gives a uniform protein network [1, 5, 50, 53, 56].

After the resting step, the thickness of the compounded sheets is reduced by passing through the sheeting rolls that have a gradually reduced gap in between. The number of sheeting rolls varies from three to five [1]. The final sheet thickness is maintained according to the type of noodles developed [54]. In modern noodle making industries, sheeting in conjunction with increased hydration has improved the eating quality of noodle. A homogenous protein matrix can be attained during sheeting that aid to develop noodle with best eating quality. The major factors involved in the sheeting process are reduction rate, speed, number of passes, temperature, size, and position of the sheeting rolls. The thickness of dough sheets must be reduced gradually in order to minimize surface damage. This can be achieved by controlling the gap setting in a series of smooth rolls [1]. After compounding, the thickness of dough sheets should be reduced to below 40 percent. The final sheet reduction should be no more than 10% before cutting. The roll diameter should decrease gradually with each successive pass, so that pressure and compression distance are lowered also. With the increase in roll diameter, the horizontal movement of sheeting rolls increases. After each passage through the roller, the length of dough sheet increases. However, over-stretching of dough sheet could occur by performing the process at very high speed. The temperature of the sheeting rolls is maintained at proper temperature to give a desirable dough sheet [1, 5, 54, 56].

3.4 Cutting

The noodles are cut into strands after the desired thickness is achieved during sheeting. The shape and width of the strands are identified by means of the cutting rolls [1, 5]. The cutting machine comprised of a pair of slotted rolls having similar slot widths. The rolls for cutting are arranged in a linear fashion, with the front one turning counter-clock wise and the rear one turning clockwise with identical speed. The cutting force is produced among the adjoining two pointed slots edges of the cutting rolls. A comb is there at the bottom of every cutting roll to avoid sticking of noodle strands to the rolls. The final shape of noodle strands is based on the slot groove, the thickness of the dough sheet and the width of the slot. The shape mostly preferred is square, rectangular and round [1]. For the specification of noodle cutter there are two systems, namely imperial and metric. In the imperial system, noodle strands is cut to a width of 25.4 mm, while in the metric system, the noodle strands of 30 mm width is cut down according to the assigned number of the cutting rolls. Finally the strands are cut into appropriate lengths through the help of length cutter. However, the noodle strands are fed continually into a moving net conveyor in case of instant noodle production that moves slowly as compared to the cutting rolls. The difference in the speed of feeding of noodles and net traveling resulted in a distinctive wave to the strands of noodles. After steam cooking, noodle strands are cut into desirable serving size [1, 5, 14].

3.5 Drying

The noodle shelf life can be extended considerably by limiting the biochemical and microbiological stability, which can be achieved by drying the noodle strands to a minimal moisture level. The process of drying is achieved by air drying, vacuum drying or deep frying [1]. Deep-frying is done in order to develop deep-fried and steamed noodles. The application of vacuum drying in the noodle industry is a newer method for drying noodle strands. Vacuum-drying of frozen noodles are usually performed in order to manufacture better quality end product. Drying by air is classified in to two basic types; hot air drying (>70 ^{o}C) and non-hot air drying (<50 ^{o}C) depending on the temperature used for drying purpose. The process of hot-air drying is applied to develop dried instant noodles and steamed noodles, while non-hot air drying is provided to develop regular dry noodles. The uncooked raw strands of noodles are hanged on rods in the drying chamber, where ventilation, relative humidity and temperature are synchronized. The rods travel through various sections of the drying tunnel. Water is evaporated from the surface of noodle by air drying. The driving force needed for removal of water is the differences in the vapor pressure of noodle surface and the partial pressure of the vapor in the air. Relative humidity, temperature, air flow rate and noodle properties are the most imperative factors that determine the drying rate of noodles. Due to the hygroscopic nature of salt, it significantly affects the diffusion of water during the process of drying. Noodles having lower concentration of salt could be dried quite easily compared to noodles with high salt concentration [1, 55].

The drying of noodles not performed properly could damage the structure of noodle resulting in cracking, splitting and over-elongation of noodle strands, which subsequently affect the handling and packaging process [1, 14]. Additionally, textural and cooking properties could also be affected severely. If the noodles are quickly dried, intense moisture gradient could result between the core and the noodle surface. When the noodles start to lose moisture, shrinking takes place. There occurs tension in the surface of noodle, while compression occurs in the core and finally resulted in deformation of noodle strands. Proper drying of noodles consists of multi-stages to avoid objectionable changes in the structure of the final product [1]. A common drying practice involves pre-drying, drying and cooling. The initial stage takes about 15 percent of the total drying time that involves a low temperature of 15 to 25 ^{o}C. The application of dry air at this stage causes lowering of moisture from 38% to below 28%. This step is important to dry the exterior of the noodle strands to avoid sticking and over-elongation of the noodle strands. Diffusion of core moisture takes place to the surface, and an equilibrium condition is attained between the surface moisture evaporation and the inside moisture diffusion. However, higher temperature of 40-50 ^{o}C and drier air of 55-60% relative humidity is given to eliminate the moisture in the second drying stage [1, 55]. Finally, the noodle strands is cooled down gradually and dried again. The gradual reduction in temperature is aimed to minimize the interior resistance in the noodle. The interest toward a healthier diet resulted in the development of hot air dried instant and steamed noodles, instead of fried noodles. Hot air is used to dry steamed noodles instead of frying to lower the water below 12 percent. They are dried by hot blast of air (70-80 ^{o}C) for a time period of 30-45 minutes [1, 5, 8, 14, 55-56].

3.6 Frying

After steaming process, instant noodles are mostly fried deeply. The strands of noodles are supplied to the frying baskets and are then dipped for deep-frying in hot oil. Usually, the frying time and temperature are 60-100 seconds and 140-160 ^{o}C, respectively. The outlet of the fryer temperature is usually kept somewhat more than that of the inlet temperature [1]. Frying is maintained carefully in order to have minimum fat and fat decomposed products, as well as have good sensory properties, Deep-frying causes moisture loss, fat uptake and starch gelatinization, as well as formation of pores in noodle both externally and internally. The water in frying noodle migrates from the core to the surface. The steam vaporization in noodle during frying process created a porous sponge texture. Oil moves into the porous structure of the noodle strands from which steam flashes out. The mechanism of mass transfer during frying is dependent on the properties of steamed noodles, as well as frying time and temperature. The moisture and oil content of fried noodles are 15-22% and 3-6%, respectively. Water contributes an important role during heating, as it aids in providing thermal energy to the noodle strands in the hot frying oil. This transfer of heat from noodle surface avoids burning due to undue drying. During heating, the exchange of water to steam takes away large quantity of contacting oil energy from the system. Adequate heat should be provided in order to obtain full gelatinization that begun during the steaming process. The cooking of deeply fried instant noodles in boiling water resulted in the swelling of starch prior to the reduction of the moisture gradient. In contrast, the cooking of deep-fried noodle by means of steeping lead to the disappearance of moisture gradient in noodle strands before attaining sufficient starch swelling [1].

3.7 Boiling

The process of boiling is simple but very crucial in regard to quality attributes of the final product. The increase in popularity of refrigerated, frozen and shelf stable noodles in recent year resulted in the rise of using boiling process in manufacturing noodles. The important factor in boiling is time and water quality. The appropriate amount of boiling water must be 10 to 20 times greater than the weight of wet uncooked noodles. If the amount of boiling water is insufficient, then longer time is needed for processing and also the noodle strands stick together without enough relative movement in the boiling water, which lead to coarse texture and non-uniform strands during cooking [1]. In contrast, excess of boiling water or intense heating can damage the noodle strands owing to the greater friction among noodle strands and boiling water. The temperature of the boiling water is generally kept at 98 ^{o}C. However, boiling time is based upon the size and shape of the noodle strands and also the type of end products. Both boiling temperature and boiling time are adjusted carefully to give optimal textural attributes. Care should be taken during cooking to keep cooking loss to a minimum level. Higher rate of hydration, pre-gelatinization of starches and greater amount of salt concentration (up to 8%) reduce the boiling time in processing rice noodle, thereby minimizing the cooking loss. Boiling water having pH of 5–6 shows little solid loss. However, solid loss increases substantially when the pH of the boiling water reaches neutrality (pH 7–8). Therefore, the adjustment of pH from slightly acidic to neutral is necessary for boiling noodles. For this purpose, organic acids such as citric acid, acetic acid, malic acid or lactic acid are commonly used to control the pH of the boiling water in order to develop good quality boiled noodles [1].

3.8 Freezing

Boiled noodle texture deteriorates soon as a result of loss of moisture among the exterior and interior of noodle strands throughout storage period. The taste of boiled noodles can be extended through fast freezing. The absorption of water greater than 40% during dough mixing is important to facilitate the attainment of desirable and pleasing texture in the end products. Noodles with greater water absorption capacity minimizes the time needed for boiling of noodles. Blending of starches is also helpful in retaining boiled noodles texture during freezing. The noodles are dipped in cold water below 5 ^{o}C and then frozen quickly by blast of cold air at $-30^{o}C$. The noodle strands can be separated easily during thawing if they are cooled to proper temperature (0−5 ^{o}C) before quick freezing. However, noodles frozen below −40 ^{o}C could spoil the structure of noodle as a result of noodle core expansion during freezing by breaking the surface of the noodles, as it freezes fully prior to the freezing of noodle core [1].

4. QUALITY CHARACTERISTICS OF RICE BASED NOODLES

The quality attributes of noodles are established by considering the visual characteristics of cooked and uncooked rice noodles. The cooking properties such as high transparency, glossiness and absence of discoloration are the important factors for purchasing noodles by the consumers. Fine straight strands, translucency, whiteness and absence of broken strands are considered as the characteristics of premium quality and better priced noodles. The noodles must remain non-sticky, chewy and firm after cooking. Good quality rice noodles must cook quickly with little cooking loss [57]. Noodle qualities i.e. uniformity of shape, size, texture and color as well as nutritional, textural and cooking properties are the key criterion for evaluating rice noodles[1, 5, 7, 30, 56].

4.1 Proximate Composition

Proximate analysis of any food sample is conducted to determine the nutritional profile of that sample and also its amount by weight in the sample. The analysis is important in understanding the nutritional advantage of that specific product in the diet [50]. Some peoples are gluten intolerant (celiac disease) and wheat flour cause digestive malfunction. The only treatment is to exclude the intake of protein mostly found in barley, oats and wheat [54, 58]. Nowadays, consumers are interested in purchasing and consuming gluten free products, as these provide health benefits by inducing low glycemic index for diabetic patients; minimize chances of celiac diseases and other allergic reactions in gluten intolerant peoples [59].

The proximate analysis of rice flour i.e. moisture, protein, ash, crude fiber, fat, amylose and amylopectin concentrations varies significantly due to the variation in genetic makeup, environmental factors and milling process [5, 13, 50, 56]. A broad range of rice varieties are cultivated in the world that shows compositional variation among them. Noodles prepared from various rice varieties shows variation in quality characteristics [5]. It was reported that the moisture, ash, protein and fat concentration of dried rice noodles varied from 5.00-8.20%, 0.24–1.51%, 7.2–10.47% and 0.36–1.14%, respectively [55-56, 60]. Han et al. [50] studied the chemical composition of nine different rice varieties (Table 3). Protein concentration was found in the range of 6.92% to 8.65% in various rice varieties. While, the amylose concentration of rice varieties ranged from 10.13% to 32.07%. Juliano et al. [21] classified rice as low amylose (10-20%), intermediate (20-25%) and high amylose concentration (> 25%). Varietal differences were found in case of ash, lipid and starch concentrations, which might also be attributed to the processing such as milling [50]. These compositional differences influence the functional, thermal, cooking, eating and pasting properties of final noodles [61]. Starch is the main component of rice flour and has significant impact on the overall quality of noodle [62]. As gluten is absent in rice noodles; the pasting, thermal and physicochemical properties of the starches would be responsible for providing a quality noodle [63]. Rice flour provides smooth and creamy texture to noodles, which gives a clean taste [64]. On the other hand, Edwards et al [65]pointed out that increasing the concentration of smaller granule starches enhanced the elasticity and visco-elastic structure of the dough and also interpreted that this differences occurred in consequence of the interaction between protein and starch. Protein and lipids are present in substantial amount, which affect the properties of rice flour. It inhibits starch granules expansion during gelatinization and inhibiting retrogradation [62].The proximate composition (moisture, ash, protein, crud fiber) of rice noodles are also affected by rice bran. The moisture level increases with the increase of bran in rice noodles. However, higher the level of bran in rice noodles improved the protein and fat concentrations [66]. Intermediate amylose rice flour was used to develop soft texture noodles [23].Ordinary milled rice grains lack certain components, while brown rice contain germ and bran also, which provide certain health beneficial ingredients like vitamins, gamma amino

Table 3. Proximate composition of flour obtained from different rice varieties [50].

Variety	Proximate concentration (%)			
	Protein	Fat	Ash	Amylose
Jinsumi	7.35±0.09^{d}	1.26±0.01^{d}	0.60±0.02^{cd}	14.91±1.97^{d}
Manmibyeo	08.65±0.13^{a}	0.87±0.03^{f}	0.67±0.04^{b}	10.13±1.09^{e}
Hanareumbyeo	7.28±0.09^{d}	0.88±0.00^{f}	0.64±0.02^{bcd}	16.73±1.54^{d}
YR24088 Acp9	7.76±0.08^{b}	0.92±0.01^{e}	0.55±0.02^{e}	21.05±2.20^{c}
Seolgaeng	6.92±0.16^{e}	1.40±0.01^{c}	0.67±0.02^{b}	16.55±1.92^{d}
Milyang 261	7.65±0.04^{b}	1.66±0.01^{b}	0.65±0.03^{bc}	32.07±3.17^{a}
Suweon517	7.74±0.12^{b}	2.17±0.01^{a}	0.77±0.03^{a}	25.58±2.84^{b}
Chenmaai	8.61±0.05^{a}	0.63±0.01^{h}	0.60±0.02^{d}	23.43±1.44^{c}
Goamilbyeo	7.51±0.09^{c}	0.83±0.01^{g}	00.65±0.02^{bc}	024.54±2.41^{bc}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

butyric acid and dietary fibers [67-68].Rice varieties having high amylose concentration showed less starch lipid complex as compared to intermediate amylose containing rice [21].

4.2 Functional Properties

The functional properties of flour plays important role in product development, as it specify the quantity of water required to develop dough of optimum consistency and also represent the properties and behavior of the flour after hydration [69]. The functional properties such as water absorption index (WAI), swelling power (SP) and water solubility index (WSI) are of major concern [56]. Thumrongchote et al. [34] determined the functional properties of rice flour obtained from different varieties, which differed significantly, as given in table 4. The WAI indicate the ability of a food product to hold water [70]. Noodles manufactured from rice flour showed higher water absorption capacity compared to other cereal flours. It was observed from the previous literatures that the WAI of rice flour ranged from 3.3–8.0 g/g [34, 71]. On the other hand, Chandra and Samsher [72] found reasonably lower WAI (1.92 g/g) in rice flour. Ahmed et al. [56] blended wheat flour with rice flour and investigated its effect on the functional properties of noodles. The incorporation of wheat flour resulted reduction in WAI. A decreasing trend in WAI was found as the proportion of wheat flour in the blends increased. Similarly, it was observed in earlier studies, that the addition of wheat flour with rice flour caused a decrease in WAI of the flour blends [73-74]. The water absorption capacity of the flour is generally based on the variation in sources. It is also significantly influenced by the level of damaged starch. Higher the level of damaged starch, greater would be the water absorption capacity [37, 75]. Similarly, starch granule size also influence the water absorption capacity. The granule size of rice starch is very small compared to other cereal starches; therefore, it offers greater surface area for water absorption [13]. Rice flour having smaller particle size tends to release more amylose into the starch gel, which resulted in quick retrogradation. The gel hardness of flour is considered to be an important factor for noodle texture [7, 9]. The compositional variations in carbohydrate, protein, fat, fiber and amylose concentration of the flour lead to changes in WAI. Greater the percentage of starches and fibers in flour, higher would be the WAI [13, 72]. However, the WAI decreases in varieties containing high amylose [13, 76]. Similarly, the bonding between protein and starch also affects the hydration capacity of noodles. High protein concentration offers greater sites to make strong bond with starches, subsequently the water absorption capacity of noodles decreases [5, 77]. As the concentration of protein increases, the

Table 4. Functional properties of rice flour from different rice varieties at a temperature of 80 ^oC. [34].

Varieties	WAI (g/g)	WSI (%)	SP (g/g)
SuphanBuri 1	7.100 + 0.709^{ab}	0.909 + 0.211^{ab}	7.165 + 0.821^{ab}
SuphanBuri 2	6.684 + 0.694^{b}	0.727 + 0.104^{b}	6.734 + 1.008^{b}
SuphanBuri 3	8.008 + 0.317^{a}	1.068 + 0.098^{a}	8.095 + 0.315^{a}
PathumThani 1	6.838 + 0.365^{b}	0.787 + 0.063^{b}	6.892 + 0.368^{b}
SuphanBuri 60	6.477 + 0.451^{b}	0.897 + 0.181^{ab}	6.535 + 0.451^{b}
HawmSuphanBuri	6.909 + 0.220^{ab}	0.748 + 0.108^{b}	6.962 + 0.216^{b}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

optimum hydration of noodle dough minimizes and vice versa [78]. Lower water absorption lead to firm noodles as favored by most of the consumers [56].

On the other hand, the water solubility index of rice flour usually ranged from 0.6 to 7.94% [34, 71, 79]. However, the WSI of wheat flour is very low compared to rice flour [80]. A soluble loss of 0.04 to 0.12 g/g was found in rice based noodles [54]. There are many factors which influence the WSI of flour. Damaged granules showed highest WSI than normal granules. The degradation of granules occurs during dry milling of cereal grains 71, 80]. Similarly, rise in temperature also causes increase in WSI [79]. The composition of flour, i.e., protein and amylose concentration also effect WSI. Higher the amylose and protein concentration, lower would be the water solubility index of the flour [81]. Flour containing lower protein concentration leads to greater leaching of solids, which is attributed to the disintegration of the starch and protein network [46].Blending of wheat flour with rice flour resulted in lowering of water solubility index [56].

Swelling power is the other important functional property, which shows the capability of starch to absorb water under a specific cooking condition of 92.5 ^oC for 30 minutes. The swelling power of rice flour ranged from 5.82 to 16.23 g/g [5, 34, 79]. Hormdok and Noomhorm [9] found that the swelling power of rice starch was 10.54 g/g. Different factors such as milling methods, processing temperature, starch granules, protein; amylose and amylopectin concentration affect the swelling power of rice flour. Heo et al. [71] studied the influence of milling method (dry milling and wet milling) and temperature on the swelling power of rice flour. The SP of wet and dry milled rice flour at temperature of 25 ^oC and 100 ^oC were 3.8 g/g, 12.6 g/g and 4.7 g/g, 10.9 g/g, respectively. Thus it shows that processing temperature and milling method significantly influence the swelling power of rice flour. On the other hand, increase in protein concentration lead to a stiff starch/ protein complex. That causes a reduction in swelling power by restricting the starch granules to imbibe water, resulting in coarse and firm noodles [82-83]. Similarly, amylose and amylopectin concentration of the starch granules pose substantial influence on the swelling power of rice flour [84]. The degradation of starch granules due to various means (milling and processing) lead to the lowering of swelling power [7, 85]. When starch is heated above the gelatinization temperature in the presence of excess water; the starch granules swells due to water imbibitions, resulting in the leaching of starch components into the solution. The amount of solubilization and the degree of swelling depends on the chemical association within the granules [39]. High concentration of amylose and strong chemical bonds minimizes the swelling power by developing an extensive network [8]. Similarly, swelling power of rice flour is reduced with the increase in the concentration of wheat flour in the blends [56]. Techawipharat et al. [47] reported that waxy rice starch has higher swelling power and solubility compared to non-waxy rice starch. Normal rice starch is intact and rigid, which could not be ruptured easily compared to waxy rice starch. Amylose acts as an inhibitor as well as diluents to swelling, while amylopectin mainly affect the swelling power of starches and subsequently influence the quality of noodles. Therefore, rice varieties with low amylose concentration give a high swelling volume [8, 30, 47]. Noodles prepared from flour with greater swelling power had softer texture [1].

4.3 Cooking Properties

Gluten is the most important factor for evaluating cooking quality. Gluten is formed on hydration of glutenin and gliadin which provide elastic and extensive texture to the dough. It minimizes stickiness and solid loss and provides firmer texture to the product [6].However, due to the lack of gluten in rice flour, some technological problem arises. So, it requires proper processing techniques and additives to modify the characteristics of starch and protein [86]. For this purpose, rice flour is pre-gelatinized that performs same function as gluten, thereby provides firm structure and avoids stickiness after cooking [86-87]. Cooking quality of rice flour depends on the genetic and environmental factors [88]. Cooking time, cooked weight, cooking loss and percent rehydration are important factors that determine the cooking properties of noodles. Lower cooking time and slight loss of solids in cooking water are prominent features of good quality noodles [80].Rice flour obtained from freshly harvested rice is usually soft and sticky compared to flour from aged rice. It is therefore important to keep harvested rice for certain period to aid in processing. During storage, changes in physical and chemical properties are observed, which influence the cooking quality of rice, especially its flavor, texture and product quality after processing. Certainly, any product, such as noodles prepared from aged rice will give less sticky texture [44-45]. Charutigon et al. [89] reported that noodle prepared from rice flour had white color but stuck together after cooking process. They further suggested that using mono-glyceride and modified starches could minimize the stickiness of cooked noodles.

The cooking time of rice based noodle is measured by cutting the oven dried noodle samples (1 gm) to about 2.0 cm length. The noodle strands are cooked by occasional stirring in a beaker having boiling water. Optimum cooking time of rice noodle is assessed by squeezing together the noodle strands between glass slides and monitoring the time of fading away of the white core of noodle strands that indicates the time of cooking [5, 56]. Usually, rice based noodles takes 5 to 9 minutes to cook [5, 9, 56]. The cooking time of rice based noodle is influenced by their higher water absorption index as compared to wheat based noodles. It is because of their smaller starch granules, which provide higher surface area for hydration that reduces the gelatinization temperature and cooking time [62]. Cooking time is also influenced by the type of starch used and the thickness of noodles strands. It is observed that thin noodle strands have short cooking time due to greater surface area for diffusion of water [7, 62].Compared to wheat based noodles, rice noodles have lower cooking time due to pre gelatinization of rice flour and higher water absorption index [86-87].Addition of various starches at different level to rice flour effected the cooking time of rice based noodles, which in turn affected the final texture of noodles. Noodles made from rice flour showed lower cooking time values compared to noodles made from canna starches, mung- bean starches and sweet potato starches. This difference was attributed to the different gelatinization temperature of each starch [22].

The cooked weight of noodle is determined by taking weight of the wet mass of noodles [5, 56]. Rice based noodles showed higher cooked weight as compared to wheat based noodles. The higher pasting viscosity, swelling power and lower amylose concentration of rice starch granules is responsible for higher cooked weight of rice noodles [22, 80]. Sandhu and Kaur (2010) found lower cooked weight for rice starch noodle than that of potato starch noodles. This variation in cooked weight might be attributed to the differences in swelling power and viscosities of these starches. A positive correlation was observed between water absorption index and damaged starch level [75], as cooked weight is the rise in the weight of noodle after cooking by the absorption of water [91]. While, percent rehydration is the relative proportion of weight of cooked noodles and uncooked noodles, that may influence the noodle eating quality (5). Researchers found percent rehydration of146 to 290% in rice based noodles [9, 22]. The rehydration ratio influences the cooking and textural properties of the noodles. High rehydration rate in rice based noodles provided a sticky and soft noodle. However, lower rehydration rate lead to a course and hard noodle texture [7, 52]. Percent rehydration showed a negative correlation with solubility and showed positive correlation with PV, CPV, HPV, setback and consistency [8]. Rice noodles showed greater rehydration ratio as compared to starch based noodles, which might be due to the variation in swelling power and their respective pasting properties [9, 22].

Cooking loss is the sum total of solid loss in cooking water [54], which is due to the solubility of starches in boiling water. It is the most prominent factor that determines the cooking quality of final product and illustrates the capability of a product to offer resistance to the structural breakdown while cooking [4]. It was observed form the previous literatures that the cooking loss values of rice based noodle ranged from 0.06–0.19 g/g [5, 22, 55, 71]. Similarly, cooking loss values ranging from 0.27% to 0.74% was recorded in various rice genotypes [8]. In contrast, Sandhu and Kaur[90] observed a relatively higher cooking loss (1.53%) in case of rice starch noodles. Ahmed et al. [56] reported significant difference in cooking loss values in noodles prepared from various blends of rice and wheat flours. Noodles made from broken rice flour/ wheat flour (60:40) showed highest cooking loss, while pure wheat flour noodle showed lowest cooking loss. However, the cooking loss value increased significantly by incorporating other starches in rice flour [55]. Noodle made from wet milled rice flour showed lower cooking loss as compared to noodles made from dry milled rice flour, that is attributed to the lower water solubility of wet milled rice flour as caused by due to lower level of damaged starch [1, 50, 71]. Amylose concentration negatively influences the cooking loss of rice noodles. Noodles containing low amylose concentration lead to higher cooking loss and vice versa [5, 23, 50]. Cooking loss showed negative correlation with CPV, HPV, setback and consistency except PV [8]. Cooking loss significantly influence the sensory properties of cooked noodle samples. The loss of solid in cooking water is influenced by variation in cooking time, protein and amylose concentrations of different rice varieties used [5, 7].It is very important to uphold the structural integrity of noodles during the cooking process. Higher loss of solids in cooking water resulted in undesirable noodles characteristics such as poor cooking tolerance or resistance, high starch solubility, which lead to sticky mouth feel [8, 71, 90, 92].

4.4 Textural Properties

Textural attributes of cooked noodles are evaluated by the mouth feel of the noodles and their resistance to chewing. A number of instruments are available for measuring the texture of noodle, as an alternative to sensory analysis [50].Textural property of rice noodle is based on flour pasting properties, swelling power and gel hardness [8]. All these physicochemical properties effect textural quality of cooked noodle, which is directly related with consumer acceptance [9]. Texture of cooked noodle is one the most critical attribute which shows consumer acceptance [50]. It is a unique property which is influenced by many ingredients like protein, water, starch and hydrocolloids that play vital role in describing the textural characteristics. The water absorption index is one of the most important factors which impart significant role on textural properties of noodles [93]. The eating quality of cooked noodles is related to cohesiveness, hardness and chewiness [94].

The texture of noodle is assessed by the help of tensile testing, firmness and recovery. Tensile testing is assessed by the establishing the breaking strength and broken length of the noodle strands. Both of these properties are interrelated and indicate the resistance of noodle strands to breakage [95]. It also reflects the way noodle swells and breaks during cooking and indicates the cooking quality and cooking tolerance of noodles. While, the distance it take prior to the breakage of noodle strands measures the extensibility [5, 13, 95]. Fari et al. [5] studied the textural characteristics of cooked rice noodles made from different rice varieties (Table 5).The tensile strength of the noodle samples prepared from various rice varieties ranged from 8.0 to 16.7kPa. On the other hand, extensibility of the noodle strands ranged from 6.0 to 11.8kPa. While, the elastic recovery and firmness of rice noodles ranged from 26.2-52.2% and 85.8-89.0%, respectively [5]. The noodles having lowest value for tensile strength entailed little time to break, which shows their less extensibility. Noodles made from high amylose rice varieties showed greater tensile strength and extensibility. It was observed that the tensile strength is positively correlated with amylose concentration. As the concentration of amylose increased, the noodle samples exhibited difficulty in breaking and stretching. Noodles with higher elastic recovery and firmness lead to good quality noodles with little solid loss in cooking water [5, 8, 92]. Tensile strength shows the ability of noodles to withstand a force applied longitudinally without tearing. Tensile strength shows the cooking behavior of the noodles, as it gives indication of noodle integrity during cooking. While, elasticity shows the capability of the deformed noodles to gain its original shape and size after the removal of applied force[8]. Thomas et al. [14] studied the tensile strength and elasticity of noodles prepared from Bario rice and Basmati rice. Noodles made from Bario rice showed higher tensile strength (46.33 kPa) as compared with Basmati rice (36.33 kPa) on initial day. While the tensile strength of noodles decreased after 3 days of storage at room temperature both in Bario and Basmati rice noodles. The amylose concentration of Bario rice was higher as compared to Basmati rice, which significantly affects the tensile strength of cooked noodle. However, the elasticity modulus of Bario rice noodle was higher (13.19kPa) than Basmati rice noodle (7.89kPa) after 3 days of storage period. The elasticity modulus decreases significantly in rice noodle after storage [14, 92].

Nura et al. [13] observed that variation in flour particle size affected the textural properties of laska noodle. Springiness, chewiness and hardness of laska noodles made from flour of smaller particle size were comparatively higher than noodles made from flour of larger particle size, characterizing better quality. Similarly, Yoenyongbuddhagal and Noomhorm [7] and Hatcher et al. [96]observed that the fine flour improves the textural properties of noodles, which is due to the quick and almost complete gelatinization of smaller particle size. Similarly, more water and heat is entered into the starch granule cores of the flours with fine particle size. The increase in paste viscosities for finer rice flour represents an increase in gelatinized starch. The higher proportion of gelatinized starch is important for rice noodle texture, since it acts as a binding agent during extrusion. Hence, the smaller particle size rice flour produces better quality noodle [1, 13]. The textural attribute of noodles is influenced primarily by proteins, fibers, starch/protein network and other supplementary constituents [60]. Rice noodles having lower amylose concentration showed higher adhesiveness, which showed the higher stickiness of the cooked noodles. However, lower adhesiveness is an indication of quality rice noodle, as it gives a clean and smooth texture [50].

4.5 Sensory Properties

Consumers usually purchase noodles from either local manufacturers or convenience stores. Their

Table 5. Textural properties of cooked rice noodles made from different rice varieties [5].

Varieties	Extensibility (mm)	Tensile strength (g)	Firmness (%)	Elastic recovery (%)
Bg 300	11.8 ± 2.5^{a}	13.2 ± 3.8^{b}	87.9 ± 2.4^{ab}	46.6 ± 8.2^{a}
Bg 352	11.4 ± 2.3^{a}	16.7 ± 3.4^{a}	8.6 ± 2.7^{a}	50.3 ± 6.1^{a}
Bg 94-1	9.2 ± 3.1^{b}	12.1 ± 4.6^{b}	88.2 ± 3.4^{ab}	48.6 ± 8.5^{a}
Bg 403	11.8 ± 2.1^{a}	12.2 ± 2.3^{b}	85.8 ± 3.9^{b}	37.3 ± 9.0^{b}
At 306	6.0 ± 1.8^{c}	13.5 ± 3.0^{b}	88.5 ± 3.1^{a}	52.2 ± 14.5^{a}
At 405	6.1 ± 1.6^{c}	8.0 ± 1.7^{c}	86.7 ± 2.6^{ab}	26.2 ± 5.4^{c}
Bw 272-6b	10.3 ± 1.5^{ab}	11.9 ± 3.3^{b}	87.6 ± 1.1^{ab}	49.4 ± 12.6^{a}
Ld 356	10.2 ± 2.6^{ab}	10.7 ± 3.6^{bc}	89.0 ± 1.4^{a}	35.6 ± 10.3^{b}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

Table 6. Sensory attributes of Laska noodle prepared from rice flours with different particle sizes using 9-point hedonic scale [13].

Particle size (μm)	Appearance	Aroma	Taste	Texture	Overall acceptability
140	4.30±1.58^{e}	6.00±1.57^{a}	5.14±1.74^{b}	3.66±1.73^{e}	3.98±1.61^{e}
125	5.14±1.40^{d}	5.74±1.52^{a}	5.24±1.48^{b}	4.44±1.46^{d}	4.80±1.46^{d}
100	5.76±1.32^{c}	5.58±1.75^{a}	5.36±1.60^{b}	5.22±1.48^{c}	5.56±1.36^{c}
80	6.44±1.18^{b}	5.64±1.69^{a}	5.80±1.46^{ab}	6.24±1.39^{b}	6.36±1.17^{b}
≤63	7.32±1.13^{a}	5.74±1.93^{a}	6.12±1.45^{a}	6.92±1.26^{a}	7.02±1.12^{a}

Mean values for each characteristic followed by different letters within a column differ significantly (P = 0.05)

purchasing decisions are mainly based upon the preliminary judgment of the noodle quality visually such as brightness, absence of undesirable specks and color [97]. The sensory attributes of cooked rice noodles are appearance, aroma, taste, texture and overall acceptability [5, 56]. Preference for each sensory characteristics varies from one consumer to another; some like raw milled rice and aromatic rice, others prefer conventional rice or the parboiled rice [98].These properties are significantly influenced by using various varieties of rice for noodle production. The sensory properties of final noodle products are evaluated by trained sensory panels [5]. The most important quality factors in this regards are texture and color of final product [15, 99]. Consumers mostly prefer hard and non-sticky noodles which are influenced by the flour amylose concentration [5, 15, 99]. The sensory attributes of cooked rice noodle is also influenced due to the variation in flour particle size (Table 6).

The important factor in the evaluation of rice noodle product is appearance. The appearance of noodle manufactured from rice flours exhibited variations, which is credited to the presence of natural pigments, i.e., polyphenols and carotenoids [100]. Color is the most important parameter used for evaluating the visual quality and is important for better marketability of noodles. Fresh noodles must maintain white colored appearance [101]. Appearance is also influenced by the interaction of starch and protein. As the interaction between protein and starch is weak, it gives opaque noodles. An increase in ash concentration also affects negatively the appearance of noodles. As ash concentration of the final noodle is less, it gives transparent product [102].The sensory scores obtained in case of appearance property of rice noodles varied from 3.5 to 7.32 on a 9-point hedonic scale [5, 13, 34-35, 65]. Thomas et al. [14] evaluated the appearance of Bario rice and Basmati rice. The appearance of Bario rice scored higher as compared to Basmati rice (6.8 and 4.3, respectively).Wheat flour is sometime blended with rice flour in order to improve the cooking and sensory properties of rice noodles [61, 100]. The first parameter assessed by the consumer in food product is color, so the evaluation of visual color as part of sensory attribute is very crucial [97].

Another important sensory property assessed is flavor, which influences the amount of food consumed by the consumer. Usually the aroma of noodle product is determined by subjective evaluation. Aroma is evaluated subjectively based on the experience of panelists by smelling. Thomas et al [14] found slightly higher acceptance rate in case of aroma of noodle made from Basmati rice (5.87) than Bario rice (5.73). Previous literature showed a sensory liking score for taste of rice noodle in the range of 5.1 to 6.7[5, 13, 103]. The panelists observed little variation in the score for taste of rice noodle samples [13].However, rice noodle blended with wheat flour showed higher acceptance (6.18−7.48) in term of aroma [86]. The aroma of cooked product is generally considered a minor quality factor than other sensory properties (taste, texture, color, etc.), as it minimally affect the consumer choice for accepting a product [5].

Texture is an important quality factor for accepting the product in the marketplace. Texture is defined as the property of food structure that can be observed in response to the applied force. The texture of rice based noodle is affected by rice variety, processing factor, amylose concentration and gelatinization temperature [5, 9]. On a 9-point hedonic scale, the sensory liking scores cooked rice noodle in term of texture ranged from 3.11 to 6.92 [5, 13, 55]. Wang et al. [104] found that rice noodle scored highest in case of hardness, while lowest score in case of slipperiness. The mean scores of native rice noodles as well as their blends with wheat flour differed significantly in regard to texture [56]. Rice noodles made from the incorporation of wheat flour in a considerable amount give desirable texture [56]. Similarly, Inglettet al. [48] found similar trend in noodles prepared from blend of rice and wheat flour. Texture is the main quality factor that determines consumer preference for the cooked noodle [105]. High quality noodle must be neither too hard nor too soft [22, 57]. Texture of rice noodle is also affected by particle size. The acceptance rate of noodles made from flour of small particle size was more as compared to the flour of large particle size [13]. Muhammad et al. [106] evaluated the stickiness, elasticity and taste of cooked rice noodles by twenty trained panelists. The noodle stickiness was judged by testing the adherence of the noodles to the tongue. While the noodle elasticity was evaluated by stretching the noodle strands until they break. The reduction in firmness is due to the lower level of protein in rice noodle as compared to wheat based noodles [107]. Generally, rice based noodles have soft, and sticky texture with lower elasticity [22]. Firmness is the main factor in representing the texture of cooked noodles [1, 5].

The overall acceptability of rice noodles depends upon appearance, aroma, taste and texture. Various researchers have found differences in the desirability and acceptance of rice based noodles. Overall acceptability score values of rice noodles on 9-point hedonic scale were in the range of 2.7 to 7.02 [5, 13, 55]. Rice noodles blended with wheat flour showed maximum acceptance scores [35, 66]. Thomas *et al.* [14] studied the sensory acceptance rate of Bario and Basmati rice noodles. Bario rice had a higher acceptability score of 6.67 compared with Basmati rice (4.8). In term of appearance and overall acceptability, noodles made from Bario rice were ranked higher as compared to Basmati rice noodles. It was observed that panelists usually give preference to firm noodle irrespective of the aroma [5]. The cooking loss of rice noodle negatively correlated with the sensory properties of noodles [71]. Maximum cooking loss causes turbidity in cooking water; thereby decreases cooking tolerance and mouth feel [56, 82]. It was observed form the previous literatures that variation in genetic makeup of rice as well as flour particle size contribute important role in final noodle acceptance [5, 13].

5. CONCLUSIONS

Recently, demand for gluten free noodles in the diet has increased due to their health beneficial effect. It reduces allergic reactions and celiac diseases in peoples, who suffer from such problems by eating wheat based products. Flour, water and salts are the fundamental ingredients that are used to prepare rice noodles. Sometime, additional ingredients i.e. emulsifiers, starches, stabilizer and colorings are added to improve the functional, physicochemical, cooking and sensory attributes of rice based noodles. The basic processes involved in the development of rice noodle involve dough mixing, sheet forming, compounding, sheeting/reduction, steaming and cutting. The variation in flour properties and processing method imparts significant role in final noodle quality. Rice based noodles are made from rice flour having appropriate protein and amylose concentration and lower ash concentration. Compositional differences and lower starch concentration influence the functional, thermal, pasting, cooking, eating and sensory properties of rice noodles. Protein concentration and amylose concentration have a positive correlation with the firmness and brightness of the noodle strands. Higher level of starch causes excessive surface swelling and cooking loss. On the other hand, ash concentrations negatively affect the brightness of noodle. Therefore, appropriate amount of these components in flours are preferred to prepare noodle with appropriate cooking and textural properties. High quality rice noodle must have appropriate textural, cooking and sensory properties with extended shelf life without microbial spoilage and oxidative rancidity.

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