Research Article

Impact of Nixtamalization and Pre-gelatinization on Functional, Cooking and Sensory Attributes of Noodles Made from Flour of High, Medium and Low-Amylose Maize Varieties

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Abstract | Maize (*Zea mays* L.) is one of the most important cereal crops of the world including Pakistan. This study aimed to assess the impact of nixtamalization and pre-gelatinization on some functional, cooking and sensory properties of the noodles made from the flour of Azam, Sarhad and Pahari maize varieties with high (22.02%), medium (14.18%) and low (10.04%) amylose content, respectively. Maize grains of these varieties were nixtamalized and milled to prepare the noodles from 25, 50 and 75% pre-gelatinized and un-gelatinized maize flours and their cooking, functional and sensory parameters were determined. Results showed that overall quality parameters of noodles were improved significantly ($p < 0.05$) with nixtamalization and pre-gelatinization. This was further observed that with increasing level of pre-gelatinization of nixtamalized flour of high-, medium- and low-amylose maize varieties. noodles cooking loss reduced from 12 to 3.02, 13 to 3.35 and 15.2 to 3.8%, respectively. Similarly, cooking time was also improved and a significant rise in terms of noodles texture was also observed. Moreover, the sensory attributes of the noodles in terms of colour, texture and overall acceptability were also improved significantly by all pre-gelatinization levels of nixtamalized maize flour. Based on overall study results, it is concluded that nixtamalization of maize grains and subsequent pre-gelatinization of their flour improve the noodles quality to acceptable levels in terms of functional, cooking and sensory attributes.

Received | Oct 10, 2025; **Accepted** | Nov 3, 2025; **Published** | November 29, 2025
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Citation | Shah, W. and I.M. Qazi. 2025. Impact of nixtamalization and pre-gelatinization on functional, cooking and sensory attributes of noodles made from flour of high, medium and low-amylose maize varieties. *Sarhad Journal of Agriculture,* 41(4): 2022-2032.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.4.2022.2032
Keywords | Maize varieties, Maize flour, Noodles, Pre-gelatinization, Nixtamalization and Quality parameters, Sensory properties.

Introduction

Maize (*Zea mays* L.) is one of the major staple crops being widely used as food and feed. It is used in the food industry to prepare different cereal-based food products such as noodles, flakes and popcorns (Mashingaidze, 2006). Maize is ranked third major cereal crops around the globe with an annual area and production of about 118 million hectares and 600 million metric tons, respectively (Suleiman et. al., 2013). In Pakistan, maize crop is being cultivated on about 1.0 million hectares with approximately 3.5 million metric tons annual production. Khyber Pakhtunkhwa (KP) province is key contributor in maize cultivation and production with about 57 and 68% share in the total maize area and production, respectively (Azam and Shafique, 2017; Khubaib *et al*., 2021). Major maize varieties being cultivated in KP province are Pahari, Jalal 2003, Azam, Sarhad, Gulabadi, Iqbal, and Borhan (Abid *et al*., 2014).

Maize grains are rich source of carbohydrates, proteins, and fiber along with vitamins, and minerals. These have low fat contents, but are enriched in protein, fiber, dietary nutrition, vitamins B6, omega-6 fatty acids, magnesium and iron (Singh *et al*., 2013; Kaushal *et al*., 2023). Maize flour is used in the same way as the wheat flour for making of different products like bread, meal and breakfast meal. Moreover, corn starch is the major ingredient of maize grains which is widely used in the preparation of different food products such as noodles, spaghettis, pasta, flakes, and corn dextrose and syrup because of its low relative price (Orhun, 2013; Sun *et al*., 2018; Zhang *et al*., 2021).

Nevertheless, noodles are considered as one of the major traditional cereal-based staple foods products which are being highly consumed in different countries of Asia and Europe (Fu, 2008). Instant noodles are internationally recognized, and their consumption is increasing day by day worldwide (Gulia *et al*., 2014). Usually, noodles are prepared by the cereal flour (such as of wheat, maize, rice or barley), starch, salt, water, and many other ingredients which are involved in improving the taste, flavor and texture of noodles (Tan *et al*., 2009). The flour of wheat is preferred in making noodles but maize flour is also used due to the property of high content of dietary fibers (Yadav and Gupta, 2015). The primary ingredient in making noodles is flour, hard wheat with low contents of fiber and protein is usually used to prepare the noodles, but it is usually poor in terms of lysine and many other essential amino acids (Fu, 2008). However, maize flour is also used for the preparation of noodles and these noodles can have attractive characteristics including high quality of cooking, smooth surface, texture and color (Fuad and Prabhasankar, 2010; Shobha *et al*., 2015).

Maize grains are usually nixtamalized to improve their physical and chemical properties. In this process, maize grains are cooked with lime (calcium hydroxide) solution, followed by overnight steeping, resulting in a moist dough (masa) by which tortillas and noodles are produced (Briones *et al*., 2000; Oluwadiran *et al*., 2025). Nixtamalization technique improves the functional, physico-chemical, and sensory qualities of maize products (Hassan *et al*., 2023). Usually, pre-gelatinized corn starch is added in the flours to improve the quality and processing properties of noodles (Sun *et al*., 2018; Li *et al*., 2020). Pre-gelatinization of maize flour improves corn starch's swelling power, solubility, gelatinization temperature, and paste stability (Hong and Liu, 2023). This treatment improves the physicochemical and functional properties of flour, resulting in high-quality flour that can be used to make a new food product (Wijanarka *et al*., 2017; Wang *et al*., 2025).

Many maize varieties are being grown in different areas of KP but not much research has been done regarding the evaluation of flour characteristics of these maize varieties, especially in terms of noodles prepared from the maize flour. In this study, the impact of nixtamalization of maize grains and pre-gelatinization of maize flour was assessed on different functional, cooking and sensory properties of the noodles made from low-, medium- and high-amylose content maize varieties being commonly grown in KP province of Pakistan. The main objective of the study was to find out the effect of nixtamalization of maize grains and the optimum level of pre-gelatinization of maize flour on functional, cooking and sensory attributes of maize noodles.

Materials and Methods

First of all, some maize varieties were selected which are commonly grown in KP province. These varieties were Pahari, Jalal, Sarhad, Gulabadi, Azam, Burhan and Iqbal. Grains of these maize varieties were procured from the Agriculture Research Institute, Tarnab, Peshawar and Pir Sabak Research Centre Nowshera. The research work was carried out at the Department of Food Science and Technology, University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan. Sound grains of selected maize varieties were individually milled using a laboratory-scale flour mill (Model No. JLGL 45; Wuhan Acme Agro-Tech Co. Ltd., Wuhan, China) to produce flour. The milled flour samples were packed and stored at room temperature in air tight polythene bags for further analysis to determine their amylose contents.

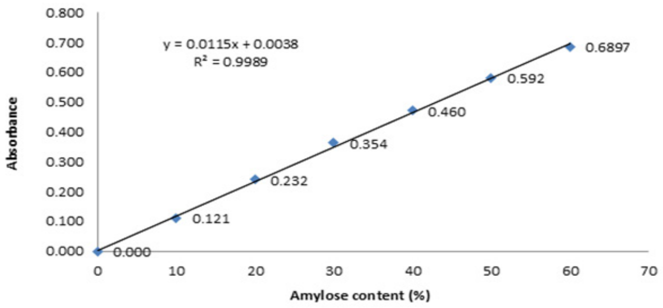

Figure 1: *Amylose standard curve obtained by Spectrophotometer at 620. Nine relative color regencies computed were obtained by open RGB and color scheme studies.*

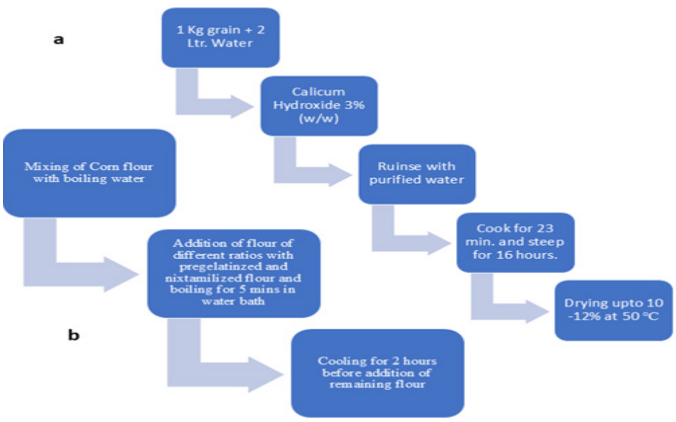

Figure 2: *Flow chart for nixtamalization (a) of maize grains and pre-gelatinization (b) of flour of selected varieties of khyber pakhtunkhwa, pakistan.*

Determination of amylose contents of the flour of selected maize varieties

The determination of total amylose contents in flour of different maize varieties was done by iodine method with certain modifications as described by Julianti *et al*. (2017). In brief, 1.0 ml of 95% ethanol solution was added in 100 mg of each sample in a beaker in three replicates. After mixing, 9.0 ml of 1 M NaOH solution was added to each sample. To gelatinize the starch, the resultant solution was boiled for 10 min in 100 ml volumetric flask on water bath. By adding distilled water, the volume of solution was made up to 100 ml. The solution was shaken well to ensure the complete mixing of all ingredients and stored at room temperature. Blank sample experimentation was also performed simultaneously. After one day, each solution was thoroughly again shaken well and 5 ml of each solution was taken and mixed with 70 ml of distilled water in 100 ml volumetric flask followed by addition of 1 ml of glacial acetic acid with the concentration of 1 M. The iodine solution was freshly prepared by mixing 10 g of KI and 1 g of iodine and making up the volume to 100 ml with distilled water. Few drops of Iodine solution were added in each of the sample solution and were kept until the appearance of dark blue color. A standard curve of starch with known amylose concentration was drawn using absorbance (%) observed by spectrophotometer (Model UV-1201, Shimadzu, Japan) at a wavelength of 620 nm.

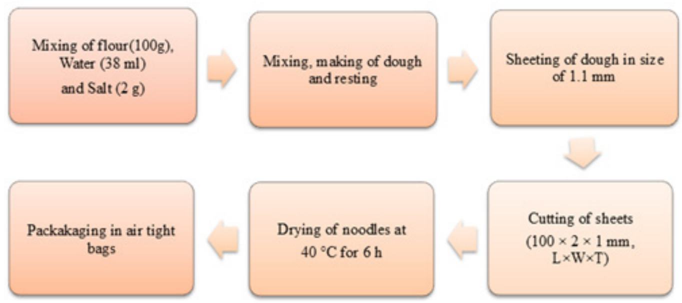

Figure 3: *Flow chart for noodles preparation from nixtamalized and pre-gelatinized high-, medium- and low-amylose maize varieties cultivated in khyber pakhtunkhwa, pakistan.*

Nixtamalization

Grains of high-, medium- and low-amylose maize varieties were nixtamalized with 3% NaOH solution for 2 h and were dry in ambient air for 16 h as shown in the Figure 2. After drying, maize grains were milled using laboratory scale flour mill. The flour of these nixtamalized grains were packed in air tight polythene bags for noodles preparation and further study. Before noodles preparation a portion of flour was kneaded in to dough and was pre-gelatinized and then added with remaining portion of nixtamalized flour.

Preparation of noodles

Noodles were prepared from the flours of three maize varieties without nixtamalization and from nixtamalized flour with and without pre-gelatinization of selected maize varieties following the method of Fari *et al*. (2011) as shown in Figure 3. Pre-gelatinization was done with four levels *i.e.*, 0, 25, 50 and 75%. The prepared noodles were packed in hermetic polythene bags and were stored at room temperature for further analysis.

Functional properties of noodles

According to the method described by Kasemsuwan *et al*., (1998), the physical parameters of the noodles were analyzed including water absorption and soluble loss. The strips of noodles were dried in at 110° C in oven for 24 h. After drying and cooling the noodles 2 g were taken in pre-weighted Petri dishes from each sample. These noodles were then soaked in water distilled for 24 h. Excess water was drained off and the weigh the noodles were observed which showed the water absorption index. The drained water was also weighted after 24 h heating at 110°C and the variation in weights of dries and soaked noodles indicated soluble loss of the noodles. The water absorption and soluble loss were computed using the following equations.

$$\text{Water absorption} = \frac{\text{weight of wet noodles}}{\text{weight of dry noodles}}$$

$$\text{Soluble loss \%} = \frac{\text{loss in weight}}{\text{weight of sample}} \times 100$$

Determination of cooking loss

The cooking water as well as the washing water used in the rehydration test was poured into pre-weighed and pre-sterilized petri dishes and dried at 105 °C in oven. The dried maize noodle samples were also measured for cooking loss (%) according to the methods reported by Hormdok and Noomhorm (2007). The residue obtained after complete drying was weighed and cooking loss was calculated using the following equation.

$$\text{Cooking loss (\%)} = \frac{\text{weight of dried residue}}{\text{weight of sample}} \times 100$$

Texture of noodles

Texture of prepared noodle samples was measured with texture analyzer (TA-XT2i, Stable Micro System London, England) by using the method of Niu *et al*. (2014). The noodles were cooked and let to drain for 5 min. The water on the noodles surface was dried gently with the help of filter paper and then the noodles were cut into length of 2.5 cm. The samples of noodles were compressed using load cell of 10 kg using cylindrical probe. The process was repeated thrice.

Sensorial properties of steamed maize noodles

The sensory properties, including color, texture and overall acceptability, were evaluated using the method described by Larmond, (1977) with a 9-point hedonic scale. The noodles were cooked and assessed by an expert panel to judge organoleptic attributes, including color, texture, appearance, and overall acceptability. The evaluation followed the procedure of the 9-point hedonic scale, where a score of 9 represented the highest level of preference and 1 indicated the lowest.

Statistical analysis

The statistical software SPSS (Version 22.0) was used for statistical analysis of the data. All research data obtained during this study was analyzed using a completely randomized design (CRD). The significance of factors was assessed using one-way analysis of variance and the respective treatment means were compared using least significant difference (LSD) post-hoc test (Steel and Torrie, 1997) at standard probability level (*i.e.* at $\alpha = 0.05$).

Results and Discussion

Amylose contents of selected maize varieties

Amylose content of any flour sample is one of the basic and important noodle parameters (Fu, 2008; Qazi *et al*., 2011). Statistical analysis of the data indicated a significant ($p < 0.05$) difference in amylose content of the selected maize varieties commonly being cultivated in KP province of Pakistan (Table 1). It was observed that maximum amylose content was recorded for Azam (22.02 %) classified as high-amylose maize variety, while the minimum amylose content was note for Jalal (6.55 %) categorized as low-amylose variety. The data also depicted that amylose content of most of maize varieties was in acceptable range for the production of noodles, except Jalal and Pahari as described by Yoenyongbuddhagal and Noomhorm (2002) and Konik-Rose *et al*. (1992). Additionally, our results of amylose contents of maize flour starches corroborate the findings of Konik-Rose *et al*. (1992) reporting that the range of amylose of different starches used for noodles may vary between 15.5 to 35%.

Impact of nixtamalization and pre-gelatinization on characteristics of maize flour noodles

The impact of nixtamalization of maize grains and different levels of pre-gelatinization of maize flours was assessed on the cooking, functional and sensory attributes of noodles. Grains of these varieties were initially nixtamalized, then milled to obtained flour and the noodles were prepared without pre-gelatinization and with pre-gelatinization (at different levels). The prepared noodles were then subjected to cooking quality (cooking loss, cooking time, texture) and sensory attributes (colour, texture and overall acceptability).

Table 1: *Percent amylose content of the flour of selected maize varieties commonly cultivated in khyber pakhtunkhwa, pakistan.*

Maize varieties	Amylose content (%)
Pahari	10.04 d
Sarhad	14.18 c
Azam	22.02 a
Burhan	21.85 a
Jalal	6.55 e
Iqbal	19.26 b
Gulabadi	17.80 b

Values assigned with different letters are significantly different from each other at $p \leq 0.05$.

Influence of nixtamalization and pre-gelatinization on cooking quality of maize noodles

Impact on cooking loss

To accept the best quality of noodles by the consumer the majority influenced by the factor known as cooking loss which is described as the total solid weight lost or dissolved in water during the process of cooking (Gianibelli *et al*., 2005; Fu, 2008; Xiang *et al*., 2025). The cooking loss values of different noodles prepared from different ratio of nixtamalized and pre-gelatinized flour samples were calculated and represented in Table 1. Statistical analysis of the noodles showed no significant ($p < 0.05$) difference between different varieties noodles. The cooking loss was found in the range of 3.02% for Azam (HNP 75%) to 15.21% for Jalal (LNP 0%). These results are in line with the finding of Afifah and Ratnawati (2017), demonstrating that the cooking loss of prepared noodles was ranged from 11.20 to 27.38%. Moreover, the results of Jobling (2004) and Fari *et al.* (2011) also reported the high cooking loss because of low amylose contents in the flour. The research by Afifah and Ratnawati (2017) found the range of cooking loss of noodles was between 10.6 to 14.3% which are consistent with the results of our findings. The total amount of the amylose content present in the flour were negatively correlated with the cooking loss (Fari *et al*., 2011), as well as the high peak viscosity which also result in higher values of cooking loss of noodles (Lase *et al*., 2013; Purwandari *et al*., 2014).

Effect on noodles' cooking time

The cooking time of noodles prepared using different maize flour samples is presented in Table 2. Cooking time is one of the important parameters of noodles. Cooking time of the noodles is the time required for noodles to absorb sufficient amount of water so that the texture of noodles becomes elastic and resembles to the wet noodles. The different combination of cooked noodles of nixtamalized and pre-gelatinized flour samples was showed in Table 2. The research by Das *et al.* (2017) revealed that the noodles prepared using different ratios of maize flour along with sago starch was observed to be from 3 to 5.4 min which is in accordance with our research. The study of Pato *et al.* (2016) and Ntukidem, (2023) revealed that the average cooking time of instant noodles prepared using maize flour was ranged from 4.30 to 5.41 min which was observed to be longer as compared to the cooking time of the commercially available instant noodles that is observed to be approximately 4 min. The more starch concentration leads towards long cooking time. The research by Ramadan (2009) and Lei *et al*., (2025) concluded that the higher density among molecules of starch in dough, results in long duration of time for water to enter in the mesh of starch. The longtime of absorption as also associated with higher content of amylopectin. Because of the free hydroxyl group present in maize flour which increased due to high content of amylose flour (Ali *et al*., 2018; Chakraborty *et al*., 2022).

Table 2: *Impact of nixtamalization and pre-gelatinization levels on the cooking quality of noodles made from the flour of high-, medium- and low-amylose maize varieties commonly cultivated in khyber pakhtunkhwa, pakistan.*

Treatment	Cooking loss (%)	Cooking time (min)	Texture (g)
HNP75%	3.02+0.02	6.0+0.02	0.64+0.04
HNP50%	6.05+0.04	5.5+0.03	0.59+0.01
HNP25%	9.07+0.01	4.8+0.05	0.51+0.03
HNP0%	12.1+0.04	4.1+0.04	0.49+0.05
MNP75%	3.35+0.04	4.7+0.03	0.52+0.03
MNP50%	6.70+0.02	4.3+0.01	0.49+0.04
MNP25%	10.05+0.03	3.8+0.03	0.44+0.03
MNP0%	13.40+0.02	3.8+0.04	0.44+0.02
LNP75%	3.80+0.05	5.03+0.05	0.46+0.04
LNP50%	7.60+0.03	4.21+0.03	0.42+0.05
LNP25%	11.41+0.01	3.60+0.01	0.39+0.01
LNP0%	15.21+0.03	3.30+0.05	0.33+0.04

Values assigned with different letters are significantly different from each other at $p \leq 0.05$.

Texture of cooked noodles

The acceptance of the final product by the consumers is largely influenced by the texture of the noodles, which is an important parameter for determining the quality index (Luo *et al*., 2015; Cao *et al*., 2017). Texture appears to be the most crucial factor in deciding the acceptability of the quality protein maize noodles. Instrumental measures of food texture can be compared to sensory results to determine if human perception of food texture is approximated by simulated mastication. Texture of the cooked noodles prepared from different ratio of nixtamalized and pre-gelatinized maize flour samples were given in Table 2. Statistical analysis showed no noticeable significant ($p < 0.05$) difference among different combinations of nixtamalized and pre-gelatinized samples. Earlier studies revealed that the texture of cooked noodles may be improved further by decreasing the firmness of noodles. This decrease in firmness can be achieved by shortening the nixtamalization times or else with the addition of hydrocolloids for example polysaccharide-based gums and proteins (Bibat *et al*., 2014 and Sunico *et al*., 2021).

Table 3: *Impact of nixtamalization and pre-gelatinization levels on sensory attributes of noodles made from the flour of high-, medium- and low-amylose maize varieties commonly cultivated in khyber pakhtunkhwa, pakistan.*

Treatment	Cooking loss (%)	Cooking time (min)	Texture (g)
HNP75%	6.6 B	7.5 A	7.2 A
HNP50%	6.2 C	7.4 A	7.0 A
HNP25%	7.0 A	6.5 B	6.6 B
HNP0%	7.0 A	6.3 BC	6.5 B
MNP75%	6.5 BC	7.2 A	6.4 BC
MNP50%	6.6 B	6.5 B	6.6 B
MNP25%	7.1 A	6.4 BC	6.6 B
MNP0%	7.3 A	6.1 C	6.5 BC
LNP75%	6.4 BC	6.4 BC	6.4 BC
LNP50%	6.5 BC	5.5 D	6.3 C
LNP25%	6.4 BC	4.3 E	5.6 D
LNP0%	7.0 A	4.3 E	5.5 D

Values assigned with different letters are significantly different from each other at $p \leq 0.05$.

Influence of nixtamalization and pre-gelatinization on sensory attributes of maize noodles

Impact on noodles color

It is one of the important attributes determining the quality of final product which influences the acceptance at the point of sale by customers is the colour (Mares and Campbell, 2001; Jia *et al*., 2019). The scores given by the panel of judges regarding the color of maize noodles are tabulated in Table 3. Statistical analysis showed a slight but significant difference ($p < 0.05$) in the color among the different selected varieties of maize. Data given in Table 3 shows that noodles made from variety Sarhad having High MNP 7.36 while data on variety Azam 6.20 showing slight less than the higher value. Furthermore, (Aravind *et al*., 2013) demonstrated that the use of high concentration of pollard in semolina noodles affects the color of spaghetti. The variations in the color of different samples noodles may be due to the presence of natural pigments in the flour including polyphenols and carotenoids (Ok et. al., 2014). Moreover, the contents of ash and the protein-starch interaction in the flour also affect product color and overall appearance as well. Flour with high ash content and weak protein and starch interaction produced noodles with low transparency and increased opaqueness, which subsequently reduced consumer acceptability for colour (Lu *et al*., 2005; Ahmed *et al*., 2016; Widjaya, 2024).

Influence on texture of noodles

The assessment for the quality of food product is highly reliant on several factors such as taste, color, texture and the nutritional value. But before considering such factors as texture and the product appearance of the product are very essential. A nutritional and tasty food product is un-preferable when the appearance and texture are not attractive (Rolls, 2012). Maize flour contains functional ingredients like protein, salt, starch, and hydrocolloids and the product texture is determined by the capacity of water retention especially in noodles (Hussin *et al*., 2020). The calculated scores for texture analysis given in Table 3 showed significant difference ($p < 0.05$) among the selected samples with the higher texture value of 7.567 for Azam HNP75%, while the lowest texture value of 4.33 for Jalal LNP0%. Texture and intactness of instant noodles are generally influenced by the raw material formula. Besides, processing also influences the texture and intactness of instant noodles (Gulia and Khatkar, 2013; Adejuwon *et al*., 2020). Additionally, the low acceptability can be associated with dilution effect of fiber (Kharel and Tamang, 2010; Cao *et al*., 2017; Qumbisa *et al*., 2022).

Overall acceptability of maize noodles

The overall acceptability of maize flour noodles showed significant difference ($P < 0.05$). The maize noodles showed the higher range of acceptability. The overall acceptability mean values of maize flour noodles are given in Table 3. The overall acceptability score was recorded higher 7.24 for Azam HNP75%, while the lowest 5.53 was recorded for Jalal LNP 0%. The main factor of the panelist's acceptance of the product and instant noodles from nixtamalized maize sample is the long shape and appearance of the noodles and looks like commercial instant noodles (Pato *et al*., 2016). The overall acceptability of the cooked noodles is highly influenced by the size of the flour used (Fari *et al*., 2011; Nura *et al*., 2011; Guan *et al*., 2020) the textural parameter of cooked noodles and the color of the product (Lee *et al*., 2005). The characteristics involved in the sensory evaluation of the cooked noodles were also exaggerated due to cooking loss (Heo *et al*., 2014). Also, the taste and overall acceptability of food can be enhanced by subjecting the raw materials to certain processing treatments, which may result in the elimination of some portions of the raw materials or modification of physicochemical properties of the end product. However, for food manufacturers in a highly competitive market and modernized society, the food taste and consumers' acceptability of a specific product are the most important factors because high consumers' acceptability indicates high food buying and profits (Lingga and Simanjuntak, 2024; Xiao *et al*., 2025).

Conclusions and Recommendations

Maize is one of the most significant grain crops and is widely used as stapple food and in various preparation of different food items such as noodles, flakes, popcorns. KP shares more than 60% maize production in Pakistan. This study assessed the flour of commonly grown maize varieties of KP regarding their amylose contents and evaluated the impact of nixtamalization and pre-gelatinization techniques on some functional, cooking and sensory properties of the noodles made from these varieties. Azam, Sarhad and Pahari maize varieties were found with high (22.02%), medium (14.18%) and low (10.04%) amylose content, respectively. Noodles made from their flour showed differential functional, cooking and sensory properties. Based on overall study results, it is concluded that both nixtamalization and pre-gelatinization had significantly improved the noodle making ability and noodles quality of all maize varieties, particularly of Azam variety. However, further research is needed in terms of characterization of thermal properties of amylose and amylopectin contents, in-depth textural analysis and large-scale acceptability testing of the noodles of maize flour.

Novelty Statement

Nixtamalization and subsequent pre-gelatinization in different levels had improved noodles quality to acceptable levels in terms of functional, cooking and sensory properties.

Author's Contribution

Wasif Shah: Performed research, analysis and write-up of this manuscript.
Ihsan Mabood Qazi: Provided technical guidelines, helped in analysis and write-up.

Generative AI and AI-assisted technology statement
The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used for this manuscript

Conflict of interest
The authors have no conflict of interest.

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