Effects of potato powder on wheat dough properties and fresh noodles quality
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ABSTRACT
Herein, the mechanism underlying the effect of potato powder on noodle quality is investigated. The pasting, rheological, and thermal properties of dough with different contents (5%, 10%, 15%, 20%, 25%, and 30%) of potato powder and fresh noodle quality were examined. An increase in the potato powder content resulted in the deterioration of the dough pasting properties as well as noodle adhesiveness and springiness, with increases in dough loss and storage modulus. It also decreased the dough freezable water content and water activity and increased the semi-bound dough water content and noodle water absorption. In addition, a broken gluten network could be observed, which became loose with an increase in the noodle cooking loss. Furthermore, a decrease in noodle smoothness and color deterioration were observed, together with an improved taste. Acceptable noodle quality was obtained with the addition of <20% potato powder.

Efectos de la papa [patata] en polvo en las propiedades de la masa de trigo y la calidad de los fideos frescos

RESUMEN
El presente estudio se propuso investigar el mecanismo que subyace al efecto de la papa en polvo en la calidad de los fideos. Para ello se examinaron las propiedades de pegado, las propiedades reológicas y térmicas de la masa con diferentes contenidos (5%, 10%, 15%, 20%, 25% y 30%) de papa en polvo y la calidad de los fideos frescos. Se pudo constatar que el aumento del contenido de papa en polvo provocó el deterioro de las propiedades de pegado de la masa, así como de la adhesividad y elasticidad de los fideos, registrándose incrementos en la pérdida de masa y el módulo de almacenamiento. Asimismo, disminuyó el contenido de agua congelable de la masa y la actividad del agua, al tiempo que se elevó el contenido de agua de la masa semiligada y la absorción de agua de los fideos. Por otra parte, se observó una red de gluten rota, que se aflojó con un aumento de la pérdida durante la cocción de los fideos. Al mismo tiempo, se redujo la suavidad de los fideos y el deterioro del color, y mejoró el sabor. Finalmente se obtuvo una calidad aceptable de fideos al adicionar <20% de papa en polvo.

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1. Introduction
Potato is one of the leading food crops in American and European countries that ranks at the fourth place among all food crops (after wheat, rice, and corn), and is also the largest vegetable crop planted across China. China is the top producer and the largest consumer of potatoes worldwide. However, processed potatoes only account for a low percentage, with a significantly lower consumption per capita, which is less than those in European and American countries (Yang et al., 2017). Potatoes can reduce fat intake in human body, improve blood lipids, and decrease blood pressure. Potatoes have inhibitory effects on many types of tumors and can aid and prevent certain diseases. Potatoes also exhibit favorable processing characteristics with good taste; as a result, these have been extensively used in food industry (Ezekiel et al., 2013; Furrer et al., 2017; Tsang et al., 2018). These can be directly used as consumer goods or as a raw material for products such as potato starch, powder, and snacks. Potato powder is a fine granular or patch-like product that is obtained by peeling, cooking, and mashing potatoes, followed by dehydration and drying, and includes all the dry matter in potatoes (Tan et al., 2019). It can be used to make cookies (Chakraborty et al., 2015), steamed bread (Cao et al., 2019; X. L. Liu et al., 2016), bread (lancu, 2015), and other foodstuffs (Zhao et al., 2017).

Noodles are one of the most commonly consumed food types in numerous countries worldwide. Noodles are popular owing to their easy production, diverse types and tastes, convenience eating, and good nutritional content (Zhang & Ma, 2016). Potato powder noodles made from potato powder and wheat flour can change the dietary structure and promote the sustainable and green development of the potato industry. Only a few studies on potato powder noodles have been reported, and most of these mainly examine the effects of potato powder on the quality of noodles. Xu et al. (2017a) studied the effects of different types of potato powder on improving the potato noodle quality and reported increases in the crude fiber, vitamin, and mineral contents of potato noodles. Sheng et al. (2017) investigated the effects of potato powders obtained through different processes on the noodle quality and found that the maximum amount of added raw potato powder was 35% and the maximum amount of cooked potato powder was 20%. Wang et al. (2016) investigated the use of extrusion in producing mixed potato powder–rice flour...
noodles and determined that the quality of extruded potato noodles was acceptable when the potato powder-to-rice flour ratio was 6:4.

Noodle quality is directly correlated with the dough pasting, rheological, and thermal properties (Gulia & Khattar, 2013; Kaur et al., 2015; Sandhu et al., 2010). Only a few studies have examined the effects of potato powder on dough properties and noodle quality (Nawaz et al., 2019). In the present study, the effects of potato powder on the microstructure as well as dough pasting, rheological, and thermal properties are investigated, and the underlying mechanism by which potato powder affects the noodle quality is elucidated. The results can be used to manufacture high-quality potato powder noodles.

2. Materials and methods

2.1. Materials

The Xuehua potato powder was provided by Inner Mongolia Fuguang Food Co., Ltd, China, and the Xiangxue high-gluten flour was obtained from Cofo Flour Marketing Management (Beijing) Co., Ltd, China.

2.2. Dough and noodle preparation

Different amounts of potato powder were added to high-gluten flour to obtain mixed flour (300 g). The amounts of blended potato powder added were 0%, 5%, 10%, 15%, 20%, 25%, or 30%. Forty percent water based on mixed flour mass was weighed and mixed with the mixed flour using a dough mixer (HMS02, Guangdong, China) at 60 rpm for one minute, 90 rpm for one minute, and 120 rpm for eight minutes. Finally, an evenly blended dough was obtained that was packaged in a sealed bag for 30 min.

Noodles were prepared using a household noodle maker (WA-BYM-12SFT, Wuxi, China). The rolling distance of the noodle maker was adjusted to 1–5 gear. The dough was folded and pressed twice at each rolling distance to form the dough sheet (thickness, 1.5 mm). Thereafter, the dough sheet was cut into raw noodles with a width and length of 5 and 20 mm, respectively. Then, an electromagnetic cooker was used to heat 500 mL of distilled water in a pot until the white core of the noodles disappeared. Thereafter, 15 noodles were cooked in boiling water.

2.3. Evaluation of dough properties

2.3.1. Pasting properties of dough

Mixed flour (3 g) containing different potato powder concentrations was weighed using an accurate electronic balance. After the addition of the sample into a sample container filled with water (25 mL), the pasting properties were measured using a rapid viscosity analyzer (TecMaster, Hägersten, Sweden). The procedure to measure the pasting characteristics was identical to that described by Tao et al. (2020). Each experiment was performed thrice. The pasting properties included the peak, trough, and final viscosities, setback and breakdown values, and pasting temperature and peak time.

2.3.2. Rheological properties of dough

Rheological properties were evaluated using a rotary rheometer (HAAKE MARS III, Massachusetts, USA). An appropriate amount of dough was added onto the test plate (20 mm in diameter) with a plate spacing of 2 mm. The excessive dough was removed, and the dough was allowed to stand for five minutes to release excess stress. The dough was then subjected to frequency scan within the elasticity range to measure the changes in the storage (G') and loss (G'') moduli as well as the loss tangent (tan δ). Each experiment was performed thrice. The test parameters included a temperature of 25°C, frequency of 0.1–40 Hz, and 0.1% strain. The non-linear regression analysis of the data was accomplished using SPSS 22.0, while the power law model was adopted to construct the fitted curve, as shown below.

\[ G' = K' f^{n'} \]  
\[ G'' = K'' f^{n''} \]  

Here, G' and G'' are the storage and loss moduli (Pa), respectively, K' and K'' are the consistency indices (Pa·s·n), f is the frequency (Hz), and n' and n'' are separate superindices.

2.3.3. Thermal properties of dough

The thermal properties of the dough were determined using a differential scanning calorimeter (DSC, Q20, New Castle, USA). First, the dough (5–10 mg) was weighed using an accurate electronic balance. Thereafter, each sample was added into an aluminum tray and sealed, while empty air-tight aluminum trays were used as controls. Then, dough enthalpy together with the endothermic peak temperature during water crystallization were determined. Each experiment was performed thrice. The temperature during the test was decreased at a rate of 5°C/min from 25°C to −40°C, and then held for five minutes before heating at the same rate to 30°C. Finally, the free water changes in the dough were measured using a water activity meter (AquaLab 4TE, Pullman, USA) at 25°C. Each experiment was performed thrice.

2.3.4. Microstructure of dough

Raw noodles were used to prepare samples with a width of 5 mm and length of 10 mm. A drying oven (SD-06, North Yorkshire, UK) was used to dry the samples at 50°C. After gold-spraying onto the sample surfaces, the samples were attached to the test platform using an electro-conductive adhesive on the scanning electron microscope (Phenom XL, Eindhoven, Netherlands) to observe the microstructure. Each experiment was performed thrice. The scanning electron microscopy (SEM) images were magnified at 500× with an acceleration voltage of 10 kV.

2.4. Noodles quality

2.4.1. Textural properties of noodles

The textural characteristics of the cooked noodles were analyzed using a texture analyzer (TMS-Pilot, Washington, DC, USA) in the texture profiling test mode. Pure water was used to wash the cooked noodles for 10 s before draining. Thereafter, three noodles were put onto the texture analyzer platform to determine the texture characteristics. Each experiment was performed three times. The testing
parameters included an original force of 0.2 N, force of 100 N, testing ratio of 2 mm/s, and deformation percentage of 50%.

2.4.2. Cooking properties of noodles
A total of 15 weighed raw noodles ($A_1$) were boiled in a pot, washed carefully with pure water for 10 s, and the washing liquid was then added to a pot for heating until the complete evaporation of water. Moreover, the pot was heated in a drying cabinet (DHG-9030A, Shanghai, China) till a constant weight was achieved. After weighing the dried samples ($A_2$), the cooking loss was determined using Equation 3. After two minutes of standing, the weight of the washed noodles was measured ($A_3$) to determine water absorption percentage using Equation 4. Each experiment was performed three times.

\[
\text{Cooking loss} (\%) = \frac{A_2}{A_1} \times 100 \quad (3)
\]

\[
\text{Water absorption} (\%) = \left(1 - \frac{A_3}{A_1 - A_2}\right) \times 100 \quad (4)
\]

2.4.3. Sensory evaluation of noodles
The sensory assessment of noodles (as shown in Table 1) was performed according to the Chinese Wheat Flour Standards for LS/T3202-199939 noodles and referring to the method described by Pasqualone et al. (2015), considering the subject characteristics. The assessment was carried out by five trained persons.

Table 1. Standard of sensory evaluation.

| Item      | Full Core | Standard of Evaluation |
|-----------|-----------|------------------------|
| Appearance|           |                        |
| Color     | 10        | White (8–10); Milk white, milk yellow (6–8); Yellow, gray and other colors (1–6) |
| Luster    | 10        | Bright (8–10); General (6–8); Dim (1–6) |
| Taste     |           |                        |
| Smoothness| 10        | Smooth (8–10); General (6–8); Not smooth (1–6) |
| Adhesiveness| 20        | Tasty, not sticky teeth (15–20); General (10–15); Sticky teeth (1–10) |
| Toughness | 20        | Chewy (15–20); General (10–15); Mushy (1–10) |
| Hardness  | 20        | Hard (15–20); General (10–15); Soft (1–10) |
| Smell     | 10        | Scent of wheat (8–10); General (6–8); No scent of wheat (1–6) |

2.5. Data analysis
The data were analyzed using SPSS 22.0 and expressed as the mean and standard deviation. Then, SPSS 22.0 was employed to determine significant differences ($P < .05$) in the means.

3. Results and discussion
3.1. Effects of potato powder on dough properties
3.1.1. Pasting properties of dough
As shown in Table 2, the dough shows decreases in the pasting parameters with an increase in the potato powder content. The dough pasting parameters are associated with the starch structure and content (Singh et al., 2018), which are different for potato in comparison to those of wheat starch. The addition of potato powder can lead to diluted gluten concentration in the dough, together with a weakened gluten network (Tan et al., 2019). Potato powder contains proteins, vitamins, and other non-starch substances, which absorb water and prevent starch from absorbing water, expanding, and gelatinizing, thereby disrupting the starch setback (Zhang et al., 2018). Most of the starch in potato powder is gelatinized starch, which is destroyed and cannot expand and gelatinize again (Nawaz et al., 2019). The phosphorus in starch also affects the pasting parameters (Krystyjan et al., 2016). Therefore, the viscosity of dough decreases with an increase in the potato powder content. The decreases in the setback and breakdown values indicate the reduced gelling capacity of the dough, which does not easily form a stable gel structure with a decrease in temperature. The starch in potato powder undergoes a certain level of pasting with poor thermal stability and high increase rate of viscosity. Therefore, the pasting peak time decreases.

3.1.2. Rheological properties of dough
As shown in Figure 1, the G’ and G" values of dough increase with an increase in the potato powder amount; the increase in G’ is higher relative to G". Additionally, tan δ decreases with an increase in the potato powder amount. Therefore, the addition of potato powder increases the viscoelasticity of the dough, with the dominance of elasticity. These results are consistent with those reported by X. L. Liu et al. (2016) and Xu et al. (2017b). The rheological characteristics of the dough are associated with gluten and starch contents as well as the starch structure (Li et al., 2014). A large

Table 2. Pasting properties of dough.

| Amount of potato powder added | Peak viscosity (cP) | Peak time (min) | Final viscosity (cP) | Breakdown (cP) | Setback (cP) | Pasting temperature (°C) |
|------------------------------|---------------------|-----------------|----------------------|---------------|--------------|--------------------------|
| 0%                           | 1607.0 ± 3.6a       | 6.13 ± 0.01a    | 1151.0 ± 8.6a        | 2246.3 ± 3.1a| 455.6 ± 8.9a | 1095.0 ± 10.4a | 78.2 ± 0.4a            |
| 5%                           | 1582.3 ± 42.6a      | 6.00 ± 0.07a    | 1130.6 ± 30.0a       | 2223.6 ± 37.4a| 451.6 ± 13.4a | 1093.0 ± 10.6a | 77.9 ± 0.8a            |
| 10%                          | 1553.0 ± 96.7a      | 5.95 ± 0.04a    | 1111.6 ± 60.6ab      | 2186.6 ± 102.6a| 441.3 ± 36.4ab| 1075.0 ± 47.1b  | 77.2 ± 0.8a            |
| 15%                          | 1524.3 ± 53.2a      | 5.95 ± 0.04a    | 1091.3 ± 44.6ab      | 2139.6 ± 70.6ab| 433.0 ± 9.6ab | 1048.3 ± 26.1b  | 77.5 ± 0.5a            |
| 20%                          | 1480.0 ± 38.7a      | 5.87 ± 0.01a    | 1059.0 ± 27.7a       | 2064.6 ± 54.3a| 421.0 ± 12.5a | 1005.6 ± 26.6a | 77.7 ± 0.9a            |
| 25%                          | 1401.6 ± 47.9a      | 5.82 ± 0.04a    | 1009.6 ± 39.2a       | 1995.6 ± 63.5a| 392.0 ± 8.8a | 950.0 ± 24.3a | 77.1 ± 0.1a            |
| 30%                          | 1374.6 ± 72.4a      | 5.76 ± 0.02a    | 984.6 ± 22.3a        | 1902.3 ± 42.7a| 390.0 ± 6.0a | 917.6 ± 20.5a | 77.4 ± 0.3a            |

Different alphabets at the top right of numbers in the same column means that differences are significant ($P < .05$). Values are the means of three replicates (means ± standard deviation).

La presencia de distintas letras en la parte superior derecha de los números de una misma columna indica que las diferencias son significativas ($P < .05$). Los valores son las medias de tres réplicas (media ± desviación estándar).
the dough, thereby decreasing the fluidity and increasing the loss modulus. In addition, wheat flour may cross-link with some non-starch substances in potato powder and affect dough viscoelasticity (Fu et al., 2016).

According to the fit curve parameters listed in Table 3, all determination coefficients ($R^2$) are >0.9, which indicate favorable curve fitting. Additionally, there is small difference in $n'$ and $n''$, suggesting that higher dough sensitivity to the alterations in frequency following potato powder supplementation. The changes in $K'$ and $K''$ are consistent to those in $G'$ and $G''$.

3.1.3. Thermal properties of dough

As observed in Table 4, with an increase in the amount of potato powder, the dough enthalpy and overall freezable water content decrease. In addition, the endothermic peak temperature decreases, semi-bound water content in freezable water increases, and free water content in the dough decreases with a decrease in the water activity (R. Liu et al., 2015). Potato powder is obtained by peeling, cooking, mashing, dehydration, and drying the potatoes. Some of the starch is damaged and many hydrophilic substances are exposed during potato powder production, which tend to bind with water (Tan et al., 2019). A substantial portion of starch in potato powder is subjected to gelatinization, with a relatively loose starch structure. Starch molecular chains break away from the constraints of starch granules, and the water binding capacity is increased (Sheng et al., 2017). In addition, some non-starch substances such as dietary fibers

| Table 3. Fit curve parameters of rheological properties of dough. |
|---------------------------------------------------------------|
| **Amount of potato powder added** | **$K'$** (Pa$^s$) | **$K''$** (Pa$^s$) | **$n'$** | **$n''$** | **$R^2$** |
| 0% | 14809 | 0.194 | 5235 | 0.153 | 0.948 |
| 5% | 15399 | 0.195 | 5449 | 0.148 | 0.963 |
| 10% | 16183 | 0.184 | 5688 | 0.142 | 0.957 |
| 15% | 17346 | 0.176 | 6062 | 0.133 | 0.980 |
| 20% | 18829 | 0.151 | 6441 | 0.120 | 0.993 |
| 25% | 19982 | 0.140 | 7008 | 0.102 | 0.993 |
| 30% | 20604 | 0.143 | 7219 | 0.101 | 0.995 |

Different alphabets at the top right of numbers in the same column means that differences are significant ($P < 0.05$). Values are the means of three replicates (means ± standard deviation).

La presencia de distintas letras en la parte superior derecha de los números de la misma columna significa que las diferencias son significativas ($P < 0.05$). Los valores son las medias de tres réplicas (medias ± desviación estándar).

| Table 4. Thermal properties and water activity of dough. |
|---------------------------------------------------------------|
| **Amount of potato powder added** | **Enthalpy** (J/g) | **Peak temperature** ($^\circ$C) | **Water activity** |
| 0 | 32.37 ± 1.36$^a$ | −3.26 ± 0.10$^a$ | 0.9672 ± 0.0006$^a$ |
| 5% | 30.7 ± 1.60$^b$ | −3.32 ± 0.16$^b$ | 0.9740 ± 0.0002$^b$ |
| 10% | 28.15 ± 2.15$^c$ | −3.52 ± 0.09$^c$ | 0.9705 ± 0.0015$^c$ |
| 15% | 20.7 ± 1.40$^d$ | −3.75 ± 0.12$^d$ | 0.9665 ± 0.0013$^d$ |
| 20% | 20.4 ± 1.13$^e$ | −4.13 ± 0.14$^e$ | 0.9621 ± 0.0022$^e$ |
| 25% | 21.75 ± 1.02$^f$ | −4.47 ± 0.13$^f$ | 0.9586 ± 0.0016$^f$ |
| 30% | 19.98 ± 1.50$^g$ | −4.81 ± 0.27$^g$ | 0.9532 ± 0.0005$^g$ |

Different alphabets at the top right of numbers in the same column means that differences are significant ($P < 0.05$). Values are the means of three replicates (means ± standard deviation).

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in potato powder also affect the thermal properties of the dough (Macagnan et al., 2016). Therefore, the addition of potato powder increases the semi-bound water level but decreases the free water content.

3.1.4. Microstructure of dough
As observed in Figure 2, the gluten network surrounds a large amount of wheat and potato powder within the noodles, and a portion of potato powder is present outside this gluten network. With an increase in the potato powder content, the gluten network is destroyed, resulting in the appearance of numerous gaps and leading to a loosened gluten network structure. When >20% potato powder is added, a more severe gluten network disruption is observed with a significant increase in the number of gaps, and the gluten network integrity deteriorates considerably. The

Figure 2. Microstructure of dough.
Figura 2. Microestructura de la masa.
addition of potato powder decreases the gluten concentration, while the water absorption capability of potato powder prevents the water absorption by gluten that is required for the formation of gluten network (Xu et al., 2017b), resulting in a disrupted gluten network of the dough.

3.2. Effects of potato powder on noodle quality

3.2.1. Textural properties of noodles

Table 5 shows the noodle textural properties. The noodle hardness increases with an increase in the potato powder amount. The starch content of potato powder increases slightly relative to that of the wheat flour content, and starch can combine with gluten protein in wheat flour to form the starch-protein network (Sandhu et al., 2010). Potato powder contains protein, vitamins, dietary fiber, and other non-starch substances. Starch and non-starch substances can fill the gluten network. During the production of potato powder, starch is severely damaged, exposing the hydrophilic substances and allowing the potato powder to easily absorb water, thereby promoting protein water absorption to form the gluten network (Tan et al., 2019). Additionally, some starch forms a paste and gelatin network after high-temperature cooking. This network has a similar function as that of the gluten protein network, which improves the noodle quality (Fu et al., 2016). Therefore, noodle hardness increases with an increase in potato powder content. Based on the analysis of the rheological characteristics, the addition of potato powder increases the G’ value of the dough, thereby decreasing the noodle springiness. According to the results of the pasting properties, the addition of potato powder decreases the surface adhesion as well as viscosity index. Therefore, noodle adhesiveness decreases with an increase in the potato powder amount. Cohesiveness is associated with noodle interior binding force (Nawaz et al., 2019). According to the dough microstructural analysis, a destroyed gluten network with numerous gaps is observed with an increase in the potato powder content, leading to a loosened gluten network. In comparison to the gluten protein network, the pre-gelatinized starch gelatin network and starch-protein network show slightly decreased binding forces. As a result, the addition of potato powder leads to slightly decreased noodle cohesiveness.

3.2.2. Cooking properties of noodles

Cooking properties are important parameters to determine the noodle quality. A small cooking loss indicates that less nutrients are lost and the noodle quality is good. As shown in Table 5, with an increase in the potato powder amount, the noodle cooking loss as well as water absorption increase significantly. Based on the analysis of the thermal properties, the addition of potato powder results in an improvement of the dough water binding capability, which increases the water absorption in noodles (Sandhu et al., 2010). The dough microstructure shows that the addition of potato powder increases the starch content, leading to a disrupted and loose gluten network. Therefore, a large amount of free starch is released into the soup during cooking, thereby increasing the cooking loss.

3.2.3. Sensory evaluation of noodles

Table 6 shows the sensory assessment data of the noodles. With an increase in the potato powder amount, the noodle luster, color, and smoothness decrease. The whiteness of the potato powder is less than that of the wheat flour. A large amount of broken starch is present in potato powder, resulting in few emission surfaces, which cause the noodles to appear dim. Potato powder particles are larger than the

| Amount of potato powder added | Textural properties | Cooking properties |
|------------------------------|---------------------|--------------------|
|                              | Hardness (N) | Springiness (mm) | Adhesiveness (N.mm) | Cohesiveness (N) | Water absorption (%) | Cooking loss (%) |
| 0                            | 1.46 ± 0.025c | 0.52 ± 0.03a | 0.058 ± 0.004a | 0.51 ± 0.03a | 92.1 ± 3.9d | 3.78 ± 0.38a |
| 5%                           | 1.85 ± 0.03c | 0.50 ± 0.03a | 0.057 ± 0.002a | 0.50 ± 0.03a | 109.8 ± 5.6c | 4.85 ± 0.26d |
| 10%                          | 2.38 ± 0.05c | 0.48 ± 0.02bc | 0.055 ± 0.002a | 0.49 ± 0.02a | 116.1 ± 5.3c | 5.64 ± 0.31c |
| 15%                          | 2.87 ± 0.04bc | 0.45 ± 0.04bc | 0.053 ± 0.003bc | 0.47 ± 0.03bc | 122.2 ± 2.1bc | 6.28 ± 0.30bc |
| 20%                          | 3.06 ± 0.08c | 0.41 ± 0.03cd | 0.049 ± 0.003bc | 0.44 ± 0.04bc | 126.6 ± 4.6bc | 6.86 ± 0.38bc |
| 25%                          | 3.36 ± 0.06c | 0.39 ± 0.02bc | 0.045 ± 0.003c | 0.40 ± 0.02cd | 130.2 ± 2.9c | 7.73 ± 0.44c |
| 30%                          | 3.52 ± 0.05a | 0.38 ± 0.03d | 0.040 ± 0.002d | 0.38 ± 0.03e | 133.4 ± 2.2e | 8.24 ± 0.35a |

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| Amount of potato powder added | Color | Luster | Smoothness | Viscosity | Toughness | Hardness | Smell | Total Score |
|------------------------------|-------|--------|------------|-----------|-----------|----------|-------|-------------|
| 0                            | 9.5   | 9.1    | 9.4        | 16.8      | 16.9      | 16.0     | 2.0   | 79.7 ± 1.3bc |
| 5%                           | 8.8   | 8.2    | 8.5        | 16.9      | 16.8      | 17.1     | 3.2   | 79.5 ± 1.5bc |
| 10%                          | 8.4   | 7.6    | 8.1        | 17.2      | 17.0      | 17.5     | 4.8   | 80.6 ± 1.8ab |
| 15%                          | 8.0   | 7.2    | 7.8        | 17.5      | 17.1      | 17.8     | 6.6   | 82.0 ± 2.1a  |
| 20%                          | 7.4   | 6.4    | 7.1        | 17.7      | 17.3      | 18.0     | 7.8   | 81.7 ± 1.7*  |
| 25%                          | 6.0   | 5.6    | 6.2        | 17.8      | 17.1      | 17.5     | 8.5   | 78.7 ± 1.5c  |
| 30%                          | 5.5   | 5.1    | 6.1        | 18.0      | 16.9      | 16.6     | 8.9   | 77.1 ± 1.9cd |

Different alphabets at the top right of numbers in the same column means that differences are significant (P < 0.05). Values are the means of three replicates (means ± standard deviation).

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![Table 5: Qualities of noodles.](image)

![Table 6: Sensory evaluation of noodles.](image)
starch particles of wheat flour and appear rougher than the small particles of wheat flour. These factors decrease the scores for appearance and smoothness (Zhang et al., 2018). Additionally, the taste viscosity score increases, as the potato powder decreases the noodle adhesiveness to improve the taste. In terms of the noodle hardness and toughness, an increase followed by a decrease is observed because the addition of a specific amount of potato powder improves the noodle quality, while excess hardness deteriorates the chewiness and taste of the noodles. The smell score increases significantly with an increase in the potato powder content. Potato powder has a strong potato scent after cooking and grinding, which improves the smell of the noodles. An overall superior noodle quality is obtained with a potato powder amount of 15–20%.

4. Conclusion

This study examines the effects of potato powder on the dough properties by analyzing the pasting, rheological, and thermal properties as well as the microstructure of the dough to elucidate the mechanism by which potato powder affects the noodle quality. The addition of potato powder deteriorates the dough pasting properties, thereby decreasing the noodle adhesiveness. In addition, it improves the dough storage loss modulus, resulting in decreased noodle springiness. Furthermore, it decreases the dough free water and freezable water contents while increasing the semi-bound water content, resulting in an increase in the noodle water absorption. It destroys the gluten network structure by reducing the structural integrity, which causes structural loosening and increases the noodle cooking loss. The addition of potato powder improves the taste, but deteriorates the color, luster, and smoothness. An acceptable overall noodle quality is obtained when 15–20% potato power is added.

Disclosure statement

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