Technological, quality and nutritional characteristics of Ramen noodles with wheat flour partially substituted by water chestnut flour

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Abstract

Ramen noodles were prepared by partially supplementing traditional wheat flour with water chestnut flour (WCF) at 30, 40 and 50% levels w/w. The composition, pasting and farinograph indices of flour blends were studied. Noodles were analysed for colour, radical scavenging and functional characteristics. Time for dough development, stability and farinograph quality number declined significantly from 5.250±0.07 to 1.20±0.01 min, 6.45±0.07 to 1.31±0.01 min and 81.50±0.71 to 18.50±0.71, respectively, after replacement. Statistically significant increment in pasting temperature (60.91±0.01 to 72.05±0.07°C), peak viscosity (1094.05±0.07 to 1099.25±0.35 Brabender Unit, BU), breakdown (310.05±0.07 to 376.05±0.07 BU), hot paste (782.05±0.07 to 996.10±0.14 BU) and cold paste viscosities (1548.10±0.14 to 1701.25±0.35 BU) were found with the addition of WCF. Non-traditional ramen exhibited significantly improved fibre, antioxidant potential and mineral content with significant reduction in % fat and caloric count. The colour variation data in ramen noodles were: L* (66.35–57.86); a* (0.24–2.08); and b* (4.03–4.47). Texture hedonic scores varied between 8.38 and 7.57 with chestnut flour level increment. Hardness of Ramen noodles samples ranged between 13.9 and 19.8 N.

Keywords: Correlation; Composite flour; Farinography; Ramen noodles; Water chestnut

Introduction

Nowadays, consumers look for quick and wholesome meals. In particular, there is great interest in wheat-based products (Saeed et al., 2023; Giuffrè et al., 2023; Giuffrè et al., 2022). Alkaline noodles, also known as Ramen noodles, offer the advantage of a shorter preparation time, a distinct flavour and colour and a chewy and springy texture (Wang, 2014). In Southeast Asia, there are three main types of alkaline noodles: fresh Cantonese noodles, partly cooked Hokkien noodles and fresh or steamed wonton noodles (Hou, 2010; Zi et al., 2022; Du et al., 2023). Widespread alkaline salts used in the preparation of ramen noodles are sodium carbonate and potassium carbonate, or a combination of the two (Li et al., 2018). Traditionally, Kansui (aqueous solution of lye stone or plant ash) was used in the formulation of alkaline noodles.

The primary ingredient of noodles is wheat (Triticum aestivum L.) flour (Marconi and Carcea, 2001). In Asia, noodles are a dietary staple that account for 20–50% of all wheat flour (WF) consumed (Hou et al., 2015; Tong, 2020; Yuliantini et al., 2020). Water chestnut (Trapa natans), also known as Singhara, is an aquatic angiosperm with floating leaves present in freshwater
Technological, quality and nutritional characteristics of Ramen noodles

Preparation of Ramen noodles

The methodology of Hou et al. (2015) was followed with minor modifications for the preparation of Ramen noodles. The supplemented dough was prepared by replacing WF with (30, 40 and 50%) WCF while a control dough was prepared with (30, 40 and 50%) WCF, aiming to elevate the nutritional profile of Ramen and contribute to sustainability in the food industry. The novel approach was to study the effect of up to 50% substitution of WF with WCF in terms of the rheological, functional, nutritional and sensory characteristics of Ramen noodles. This combination of water chestnut and WF is not reported for alkaline noodles formulation.

Materials and Methods

The chemicals used in this study were of analytical grade, sourced from Dae-Jung Chemicals in South Korea and Sigma-Aldrich in Germany. The flour samples were purchased from a local supermarket in Karachi who procured flour from Sukkur Grains (Pvt.) Ltd. having an extraction rate of 50% and kept in airtight plastic containers at refrigeration temperature until used.

Preparation of Ramen noodles

The methodology of Hou et al. (2015) was followed with minor modifications for the preparation of Ramen noodles. The supplemented dough was prepared by replacing WF with (30, 40 and 50%) WCF while a control dough sample was made with WF (100%). These percentages were chosen to test a significant quantity of chestnut flour. Then, NaCl (1%) and Sodium Carbonate (1%) based on flour weight (db) was dissolved in water to make kansui water. The kansui temperature was maintained to 26°C and it was gradually added to the flour. Manual kneading was performed until formation of a perfect dough ball. Afterwards, the dough was kept covered with cling wrap for 15 min. The rested dough ball was then sheeted to 3 mm thickness and left again for 30 min at room temperature. Subsequently, it was further sheeted to a thickness of 1 mm. The sheets were then cut and shaped into ramen noodles. Subsequently, the noodles were air dried for an hour and stored in zip lock bags for further analysis.

Proximate analysis

The standard methodologies of AACC international (2000) for protein (Method 46–13), moisture (Method 44–40), ash (Method 8–01), fat (Method 30–25) and crude fibre (Method 32–10) were followed to evaluate the composition of flour blends and ramen noodles. Total carbohydrates in flour composites and noodles were calculated by employing the following equation;

\[
\text{% carbohydrates} = 100 - (\text{% protein} + \text{% fat} + \text{% ash} + \text{% fibre} + \text{% moisture})
\]

Dough rheology

The Brabender® Farinograph (GmbH & Co.KG, Germany) was used to study the effect of multiple levels of WCF addition to WF on rheology of ramen noodles dough by employing the recognized AACC international Method 54–21 (2000). Consistency and degree of softening (DoS) expressed as BU, (WA, dough development time (DDT), dough stability (DS) and farinograph quality number (FQN) were observed.

Pasting profile of wheat and WCF composites

The Brabender® Micro-Visco-Amylograph (GmbH & Co.KG, Germany) was used to explore viscosity profile of flour composites. The methodology outlined by Moin et al. (2016) was followed. Briefly, flour suspension of 10% (w/w, db) was prepared with distilled water and was heated from 40°C to 95°C at a heating rate of 3°C/min. Afterwards, it was held at 95°C for 10 min. The slurry was then cooled back to 50°C at a cooling rate of 3°C/min and kept at 50°C for 10 min. Pasting temperature (PT was expressed as °C), peak viscosity (PV), hot paste viscosity (HPV), breakdown viscosity, cold paste viscosity (CPV) and setback viscosities were expressed as (BU).

DPPH assay

The radical-scavenging activity (%RSA) of ramen noodle samples was determined by means of the DPPH assay. The protocol of Littardi et al., (2020) was followed, with some modifications. Ramen noodles (1 g) were mixed with 10 mL of methanol–water solution (70:30) for an hour at room temperature. Afterwards, the extract was filtered through a pleated filter and then dried at 40°C.

Materials and Methods

The present study developed Ramen noodles enriched with WCF, aiming to elevate the nutritional profile of Ramen and contribute to sustainability in the food industry. The novel approach was to study the effect of up to 50% substitution of WF with WCF in terms of the rheological, functional, nutritional and sensory characteristics of Ramen noodles. This combination of water chestnut and WF is not reported for alkaline noodles formulation.

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DPPH assay

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Materials and Methods

The present study developed Ramen noodles enriched with WCF, aiming to elevate the nutritional profile of Ramen and contribute to sustainability in the food industry. The novel approach was to study the effect of up to 50% substitution of WF with WCF in terms of the rheological, functional, nutritional and sensory characteristics of Ramen noodles. This combination of water chestnut and WF is not reported for alkaline noodles formulation.
Ramen noodles prepared from composite flours were organoleptically evaluated by using a 9-point Hedonic scale (ranges from 9–like extremely to 1–dislike extremely) by a panel of 10 semi-trained panelists. The protocol of Tomar et al. (2021) was followed. The assessors were female graduate students of Jinnah University for Women, Pakistan. They evaluated three digit randomly coded noodle samples in terms of aroma, colour, taste and texture in a bright and well-ventilated laboratory. Drinking water was served along with ramen samples.

### Statistical analysis

All analyses were performed in triplicates (n = 3), except for sensory analysis, which was performed in 10 replicates. Three specimens were analysed. The experimental results were subjected to analysis of variance (ANOVA) and Pearson’s correlation using the IBM Statistical Package for the Social Sciences (SPSS) software (version 17.0; IBM Corp., Chicago, IL, USA). Duncan’s multiple range test was used to identify significant differences between different levels of WCF supplementation with a 95% confidence level (p<0.05). Pearson’s correlation between the amount of water chestnut and rheological, compositional, colour and cooking characteristics of ramen noodles was evaluated.

### Results and Discussion

#### Compositional analysis of flour blends

The moisture, protein and fat percentages were found significantly higher in WF when compared with composite flours having (30, 40 and 50%) WCF (Table 1). The lower moisture measurement of WCF blends is attributable to their higher WA which may occur as a result of reduced gluten content and a lack of continuity in the gluten network, causing a more rapid moisture permeation into samples with lower protein content.

With regard to our data, it can be observed that the moisture content decreased with the increase of wheat–water chestnut composite from 11.27 to 7.86% for 0% WCF and 50% WCF, respectively. Similar behaviour was found in Ramen noodles with a decreasing trend ranging between 32.39 and 28.70% for 0% WCF and 50% WCF, respectively (Table 1). The ash content increased by 268% in
flour composites and by 185% in Ramen noodles when the percentage of WCF was implemented in the recipe (Table 1). The protein percentage was similar both in chestnut flour composite and in Ramen noodles, also in this case the quantity of protein decreased with the increase of WCF. Similar protein behaviour was found by Michalak-Majewska et al. (2020) in both uncooked and cooked pasta prepared with an increasing onion skin powder content.

The fat quantity of our samples decreased by 3.09 times in flour blends and by 4.3 times in Ramen noodles, with the increase of WCF (Table 1). This decrease may be considered positively by consumers requiring a low fat product. The substitution of WF with WCF provided a significant improvement in crude fibres, which is very important for the modern human diet (Giuffrè and Giuffrè, 2023, de Carvalho Correa et al., 2024).

**Effects of WCF on compositional analysis of ramen noodles**

The compositional analysis findings of ramen noodles are presented in Table 1. The addition of salts (NaCl and NaHCO₃) in the formulation of ramen noodles is the reason for higher percentage of ash (5–10%) in all ramen noodle samples. However, mineral content of noodles significantly increased with the rise in the substitution level of WCF. The percentage of proteins in noodles significantly reduced with the increase of WCF. This was due to the dilution of gluten present in WF. Moisture content (%) decreased with the increase in the quantity of WCF in the noodle formulation. Noodles prepared with wheat-banana flour blend and wheat-chestnut blend also exhibited a similar percentage moisture trend (Ritthiruangdej et al., 2011; Altiner and Merve, 2020). A statistically significant reduction in the fat percentage of noodles could be observed after the addition of WCF in the noodles. Noodles prepared with WCF substitution were found to have improved crude fibre content. Moreover, a 50% WCF substitution had a significantly pronounced impact. The caloric value for WCF substituted noodles significantly reduced when compared to control (WF) noodles. The enhanced percentage of crude fibre and reduced calories per 100 g suggest the appropriateness of WCF noodles for gut health and a calorie conscious population.

**Farinograph of ramen noodle dough substituted with WCF**

The Farinograph® indices of WF and WF–WCF blends are summarized in Table 2. A statistically significant decline in WA was observed with the incorporation of (30 and 40%) WCF. A similar decline in WA of wheat–water chestnut and wheat–amaranth blends was also reported by Krishnaiya et al., (2016) and Sindhuja et al. (2005), respectively. The level of starch crosslinks within noodles has a direct influence on their cooking characteristics. In cases where the gluten network within the noodles is weak and the starch crosslinking is not well-established, it can result in disintegration or even breakage of the noodles during the cooking process (Tian et al., 2022). Interestingly, at 50% WCF level, the dough

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**Table 1. Effect of water chestnut flour addition on compositional analysis of flour blends and Ramen noodles.**

<table>
<thead>
<tr>
<th>Wheat–water chestnut flour composites</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Water chestnut flour (%)</td>
<td>Moisture (%)</td>
<td>Ash (%)</td>
<td>Protein (%)</td>
<td>Fat (%)</td>
<td>Crude fibres (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>11.27±0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.95±0.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.51±0.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.26±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.54±0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>9.08±0.24&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.64±0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.61±0.66&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.31±0.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.99±0.16&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>8.37±0.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.08±0.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.45±0.31&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.15±0.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.19±0.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>7.86±0.41&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.55±0.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6.31±0.20&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.73±0.03&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.19±0.16&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wheat–water chestnut noodles</th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water chestnut flour (%)</td>
<td>Moisture (%)</td>
<td>Ash (%)</td>
<td>Protein (%)</td>
<td>Fat (%)</td>
<td>Crude fibre (%)</td>
<td>Energy value (kcal/100g)</td>
</tr>
<tr>
<td>0</td>
<td>32.39±0.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.30±0.62&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.27±0.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.29±0.19&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.51±0.13&lt;sup&gt;c&lt;/sup&gt;</td>
<td>251.58±1.55&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>30</td>
<td>30.20±0.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.83±0.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.22±0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.48±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.57±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>247.99±2.08&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>40</td>
<td>29.31±0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.78±0.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.40±0.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.38±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.61±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>247.07±1.76&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>50</td>
<td>28.70±0.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.83±0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.04±0.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.35±0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.65±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>244.17±0.38&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Values ± standard deviation within the same column having different lowercase superscripts are statistically significantly different at p<0.05.
exhibited significantly higher WA. The significantly highest ash and crude fibre content of 50% WCF–WF flour blend (Table 1) could be the reason for its higher WA, as these components in flour exhibit higher water affinity (Mansoor et al., 2019). The WF substitution with (30, 40, 50%) WCF significantly minimized the time to achieve optimum consistency (500 BU) of dough (DDT), stability and Farinograph™ quality number (FQN) when compared to control (0% WCF). However, the DDT of 50% WCF (4.25 min) dough was significantly prolonged when compared to DDT of 30% and 40% (1.20 and 1.75, respectively) WCF substituted dough. The struggle between WF and WCF for water of hydration for proteins and dough development could be the cause of this 3.54 and 2.42 times significant deceleration in DDT at 50% WCF level (1:1 WF and WCF ratio) in comparison to DDT of 30% and 40%. The consistency value of dough (FU) significantly decreased with an increased WCF level. The significant fall in DS and significant increase in DoS after WCF incorporation when compared to control (100% WF) suggested a decline in dough strength. The dilution of gluten protein caused the formulation of weaker WCF dough. A similar trend of DoS was reported in the study by Švec et al., 2018) on WF-WCF composites. The drop in FQN with the increasing quantity of WCF could be due to the inclusion of non-glutinous proteins in the flour blend.

Viscoamylograph

Pasting properties are an essential index in the determination of the baking and cooking traits of flours. When the flour and water slurries are subjected to heat and agitation, the starch granules are enlarged and completely dislocated. Gelatinization temperature, breakdown, hot paste and cold paste viscosities significantly increased with the increment in the level of WCF substitution in WF–WCF composites (Table 3). The maximum viscosity attained by gels also increased significantly after addition of WCF. However, 50% substitution with WCF caused a reduction in PV. This is in accordance with the observations of 55% WCF–WF blend by Krishnaiya et al. (2016).

A similar trend was observed by Biao et al. (2020) by incorporating more than 15% mushroom flour, which led to a notable increase in the WA capacity and PV of the mixed flours. As the proportion of mushroom flour increased, the DS time decreased. In addition, the inclusion of mushroom flour resulted in a reduction of both gelatinization temperature and shear modulus values.

The highest setback (720.5 BU) was observed in 50% WCF substituted sample. In the study by Singh and Singh (2010), it was reported that breakdown viscosity of flour is inversely proportional to the amount of protein in regular wheat and durum wheat cultivars. A parallel trend was also observed in the present study (Table 1 and 4). The setback viscosity corresponds to the retrogradation tendency of a gel, suggesting significantly higher staling propensity of noodles prepared with 40% and 50% WCF flour. On the contrary, substitution with WCF to a lower level (30%) caused significant reduction in setback when compared to un-substituted WF noodles.

Effect of water chestnut addition on DPPH (2,2-diphenyl-1-picrylhydrazyl)

The DPPH assay is widely applied to many wheat-based products to evaluate their radical scavenging activity (Masutti et al., 2020; Sidari et al., 2020; Ghardaloo et al., 2023). The effect of WF replacement with WCF (30, 40 and 50%) on antioxidant activity of Ramen noodles was studied in terms of DPPH per cent inhibition (Table 4). With increased WCF quantity in the formulation of Ramen noodles, statistically a significant increase in DPPH free radical scavenging was observed. This could be attributed to the polyphenolic compounds present in WCF. Similar % inhibition results are reported for the cookies and flat bread prepared with WF–WCF blends (Shafi, et al., 2016; Shafi et al., 2017). The lower % inhibition of WF was due to the fact that wheat polyphenols are mostly found in the bran fraction and during the flour refining process, these polyphenols are lost. On the contrary, WCF contains higher total phenolic content in bound form and antioxidant activities than soft WF.
Cooking properties of ramen noodles

The effect of WF substitution with WCF on the cooking properties, including time for cooking, WU and CL is summarized in Table 3. A statistically significant \( p<0.05 \) increase in CL was observed with an increased amount of WCF in ramen noodles. Elevated CL showed poor radical scavenging activity in uncooked pasta. They added \( 0, 2.5, 5 \) and \( 7.5\% \) onion skin powder to the pasta recipe and found the following DPPH values – \( 1.6, 2.5, 6.2 \) and \( 7.8 \) mmol TE/g d.m. They also found that the cooking procedure did not reduce the radical scavenging activity.

Texture evaluation of Ramen noodles

The texture of cooked noodles was studied in terms hardness (N), which is the force required to rupture the noodle. The hardness depicts the force needed to chew a noodle. The control sample exhibited significantly the lowest hardness value when compared to WCF substitute noodles (Figure 1). The strength of Ramen noodle samples ranged between 13.9 and 19.8 N. It could be observed that with the increase in the level of WCF in noodles, the force of compression increased significantly. This was possibly due to a reduction in the amount of starch and increased fibre content (Table 1) in composite flour noodles. The starch in flour contributed to a higher protein pastas with lower solid leaching and increased fibre content (Table 1) in composite flour may cause discontinuity in the gluten network, causing quicker moisture penetration, consequently accelerating optimum cooking time (Manthey et al., 2004; Deng et al., 2023). Noodles prepared from WF blends with colocasia, water chestnut and sweet potato flours also exhibited significantly shorter CT (Manthey et al., 2006). WU upon cooking is the ability of noodles to retain water and consequently gain weight. A significant drop in WU was observed in WCF noodles when compared to WF. Lesser WU upon cooking leads to harder noodle texture, whereas softer and stickier noodle texture is the outcome of excessive WU. It was observed that incorporation of WCF facilitated the penetration of water, leading to shorter cooking time but retention of water was poor which led to harder texture of WCF containing noodles (Figure 1).

Table 3. Effect of water chestnut flour addition on pasting characteristics of composite flour.

<table>
<thead>
<tr>
<th>Water chestnut flour (%)</th>
<th>Pasting temperature (BU)</th>
<th>Peak viscosity (BU)</th>
<th>Breakdown (BU)</th>
<th>Hot paste viscosity (BU)</th>
<th>Cold paste viscosity (BU)</th>
<th>Setback (BU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>60.91±0.01(^a)</td>
<td>1094.05±0.07(^a)</td>
<td>310.05±0.07(^a)</td>
<td>782.05±0.07(^a)</td>
<td>1548.10±0.14(^a)</td>
<td>630.00±0.00(^b)</td>
</tr>
<tr>
<td>30</td>
<td>61.11±0.16(^b)</td>
<td>1086.05±0.07(^b)</td>
<td>312.05±0.07(^b)</td>
<td>882.05±0.07(^b)</td>
<td>1654.05±0.14(^b)</td>
<td>620.50±0.71(^c)</td>
</tr>
<tr>
<td>40</td>
<td>69.05±0.70(^c)</td>
<td>1099.25±0.35(^c)</td>
<td>328.05±0.07(^c)</td>
<td>892.05±0.07(^c)</td>
<td>1698.05±0.07(^c)</td>
<td>632.50±0.71(^d)</td>
</tr>
<tr>
<td>50</td>
<td>72.05±0.07(^d)</td>
<td>1088.50±0.70(^d)</td>
<td>376.05±0.07(^d)</td>
<td>996.10±0.14(^d)</td>
<td>1701.25±0.35(^d)</td>
<td>720.50±0.71(^e)</td>
</tr>
</tbody>
</table>

Note: Pasting profile findings ± standard deviation within the same column having different lowercase superscripts are statistically significantly different.

Table 4. Effect of water chestnut flour incorporation on antioxidant and cooking indices of Ramen noodles.

<table>
<thead>
<tr>
<th>Water Chestnut flour (%)</th>
<th>Radical scavenging activity DPPH assay (%)</th>
<th>Cooking time (min)</th>
<th>Cooking loss (%)</th>
<th>Water uptake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>31.15±0.62(^a)</td>
<td>6.78±0.19(^a)</td>
<td>3.99±0.04(^a)</td>
<td>1.79±0.04(^a)</td>
</tr>
<tr>
<td>30</td>
<td>43.22±1.35(^b)</td>
<td>5.68±0.17(^b)</td>
<td>4.85±0.07(^b)</td>
<td>1.65±0.03(^b)</td>
</tr>
<tr>
<td>40</td>
<td>62.45±0.38(^c)</td>
<td>5.23±0.26(^c)</td>
<td>4.94±0.05(^c)</td>
<td>1.62±0.03(^c)</td>
</tr>
<tr>
<td>50</td>
<td>78.49±0.55(^d)</td>
<td>5.21±0.25(^d)</td>
<td>5.07±0.07(^d)</td>
<td>1.58±0.03(^d)</td>
</tr>
</tbody>
</table>

Note: Findings± standard deviation within the same column having different lowercase superscripts is statistically significantly different.
network-forming structure and enhanced absorption of water into the Ramen noodle as evidenced by per cent WU upon cooking (Table 4). Moreover, increased hardness led to significantly lower texture scores of highly substituted WCF samples (40 and 50%) than the control sample (Table 5).

Colour and sensory analysis of Ramen noodles

The colour analysis illustrated that as the amount of WCF in the ramen noodles increased (30%, 40% and 50%), there was a significant and gradual decrease in lightness ($L^*$) (Table 5). A similar decline in $L^*$ value was observed when Chinese chestnut was incorporated into bread at increasing levels (Wang et al., 2023). The redness ($a^*$) and yellowness ($b^*$) increased significantly after WCF incorporation. However, the increase in ($b^*$) was not pronounced but yet significant. Ramen noodles made with WCF turned out darker ($L^*$ ranges between 57 and 59) than WF and had a reddish/yellow hue.

All the studied sensory attributes scored between 7 and 8 hedonic points, suggesting the acceptability of all combinations of ramen noodles (Table 5). The sensory evaluation showed that semi-trained assessors could not find any significant change in the taste and aroma of WCF supplemented Ramen when compared to WF. Nevertheless, WF and 30% WCF–WF noodles scored significantly higher for colour than 40 and 50% WCF–WF noodles. Moreover, the texture of 40 and 50% WCF–WF noodles scored significantly fewer hedonic points than WF and 30% WCF–WF noodles. This could be due to significantly increased losses upon cooking at higher WCF level (Table 4). The losses during cooking made the noodles stickier, consequently, negatively affecting the sensory acceptability of the ramen containing WCF (Shiau and Yeh, 2001). This trend is in accordance with the organoleptic evaluation data of instant noodles prepared with black carrot powder (Singh et al., 2018).

Table 5. Effect of water chestnut flour supplementation on colorimetric and organoleptic properties of Ramen noodles.

<table>
<thead>
<tr>
<th>Water chestnut flour (%)</th>
<th>Colour values</th>
<th>Hedonic scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L^*$</td>
<td>$a^*$</td>
</tr>
<tr>
<td>0</td>
<td>66.35±0.47</td>
<td>0.24±0.02</td>
</tr>
<tr>
<td>30</td>
<td>59.81±0.16</td>
<td>1.37±0.08</td>
</tr>
<tr>
<td>40</td>
<td>58.57±0.42</td>
<td>1.64±0.09</td>
</tr>
<tr>
<td>50</td>
<td>57.86±0.10</td>
<td>2.08±0.16</td>
</tr>
</tbody>
</table>

Note: Values ± standard deviation within the same column having different lowercase superscripts are significantly different. $L^*$ value depicts the lightness (100: perfect white/0: perfect black), $a^*$ value illustrates (+) redness/(-) greenness, and $b^*$ value highlights (+) yellowness/(-) blueness of ramen noodles.
Table 6. Correlation of water chestnut flour addition with rheological, colour values and cooking characteristics.

|                  | DDT  | Stability | DoS  | FQN  | PT   | PV   | SB   | BD   | %RSA | L*   | a*   | b*   | CT   | CL   | WU   | MC   | Ash  | Protein | CF  |
|------------------|------|-----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|
| WCF level        | –.436| –.709*    | .888**| –.254| .832*| –.187| .606 | .753*| .930**| –.980**| .932**| .924**| –.957**| .974**| –.952**| –.977**| .979**| –.960**| .683*|
| DDT              | .937**| –.704 | .967**| .036 | –.741*| .431 | .260 | –.110| .599 | –.410 | –.171 | .575 | –.619 | .422 | .380 | –.427 | .342 | –.341 |
| Stability        | –.849**| .828* | –.311 | .540 | .128 | –.070 | .443 | .828*| –.676 | –.469 | .805* | –.832*| .685 | .658 | .693 | .627 | –.564 |
| DoS              | –.613 | .484 | .054 | .321 | .461 | .678 | –.939**| .897**| .762 | –.934**| .957**| –.835**| –.830*| .859**| –.792*| .750* |
| FQN              | .269 | –.759* | .548 | .417 | .098 | .434 | –.244 | –.016 | .408 | –.465 | .245 | .193 | –.243 | .141 | –.192 |
| PT               | –.444 | .784* | .890**| .965**| –.723*| .807*| .830*| –.737*| .689 | –.801*| –.844**| .824*| –.879**| .702 |
| PV               | –.866**| –.766*| .435 | .011 | .246 | .432 | .432 | –.558 | .616 | .589 | .636 | .550 |
| SB               | –.768 | .766* | .766*| –.444 | .636 | .766*| –.474 | .432 | –.558 | –.616 | .589 | .636 | .550 |
| BD               | .910**| –.610 | .770*| .858**| –.635 | .593 | –.706 | –.757*| .735 | –.779*| .663 |
| %RSA             | –.848**| .919**| .943*| –.851**| .835**| –.859**| –.908**| .926**| –.929**| .680* |
| L*               | –.973**| –.869*| .956**| –.987**| .953**| .948**| –.941**| .905**| –.639* |
| a*               | .915**| –.947**| .965**| –.950**| .960**| .964**| –.932**| .683* |
| b*               | .956**| –.988**| .979**| –.979**| .979**| .979**| –.979**| .979** |
| CT               | –.952**| .908**| .946**| –.937**| .861**| –.635*|
| CL               | –.944**| –.953**| .960**| –.912**| .652* |
| WU               | .917**| –.905**| .918**| –.504 |
| MC               | –.978**| .905**| –.717**|
| Ash              | –.945**| .711**|
| Protein          | –.655*|

Where, WCF; Water chestnut flour, DDT; Dough development time, DoS; Degree of softening, FQN, Farinograph quality number, PT; Pasting temperature, PV; Peak viscosities, SB setback, BD; breakdown viscosity, %RSA; Per cent radical scavenging activity, L* value; lightness (100: perfect white /0: perfect black), a* value; (+) redness/(-) greenness, b* value; (+) yellowness/(-) blueness, CT; Cooking time, CL; Cooking loss, WU; Water uptake by noodles, MC, Moisture content of ramen noodles.
Conclusion

The study highlights the utilization of a nonconventional resource to develop healthier food options and contribute to sustainability in the food industry. The findings suggested that there is an opportunity to develop nutraceutical noodles with supplementation by non-traditional sources such as WCF, owing to the pronounced improvement in antioxidant potential, mineral and fibre contents, and with lower calorie and fat content. However, regarding various treatments carried out in this study (substitution with chestnut flour at 30, 40, and 50%) only substitutions up to 40% give acceptable outcomes. As the percentage of WCF increases, the gluten content reduces, thus hardness of noodles and CL increase. Therefore, fortification from 50% or onwards will negatively affect the physical properties of noodles. The sensory analysis showed that the incorporation of WCF in the ramen noodle recipe influenced the response of panelists and characterized the food product. Further research is needed to optimize the formulations with additives and different processing conditions for WCF-based Ramen noodles to enhance their commercial viability.

Author Contributions

Mehak Ahsan, Abeera Moin and Angelo Maria Giuffrè conceptualized the study; the methodology was formulated by Mehak Ahsan; Abeera Moin and Angelo Maria Giuffrè were in charge of software; validation was done by Abeera Moin, Humaira Ashraf and Angelo Maria Giuffrè; formal analysis was performed by Abeera Moin, Iqra Manzoor and Maliha Kamran; Iqra Manzoor and Maliha Kamran initiated the study; Mehak Ahsan did the data curation; Abeera Moin was in charge of resources; original draft preparation was done by Abeera Moin; review and editing was done by Mehak Ahsan, Abeera Moin and Angelo Maria Giuffrè; visualization was done by Mehak Ahsan, Abeera Moin and Angelo Maria Giuffrè; Humaira Ashraf, Abeera Moin and Angelo Maria Giuffrè supervised the study; project administration was done by Mehak Ahsan and funding acquisition was done by Angelo Maria Giuffrè.

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References

Committee AAOC. 2000. Approved methods of the American association of cereal chemists. AACC.

Giuffrè A.M., Caracciolo M., Capocasale M., Zappia C. and Poiana M. 2022. Effects of shortening replacement with extra
Cordia myxa


Ahsan M et al.


