

Quality and textural analysis of noodles enriched with apple pomace

Jingwen Xu¹  | Jayne E. Bock¹ | Dave Stone²

¹Wheat Marketing Center Inc, Portland, OR, USA

²Food Innovation Center, Oregon State University, Portland, OR, USA

Correspondence

Jingwen Xu, Wheat Marketing Center Inc, Portland, OR 97209, USA.
Email: hljxujingwen@gmail.com

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Abstract

Apple pomace, rich in fiber and polyphenolics, has been incorporated in noodles to introduce health benefits. The pomace was dried to a final moisture content of 4.8% (wt/wt) and finely ground into powder before being added (5%, 10%, 15%, and 20% flour weight basis, fwb) to Chinese raw noodles. Noodles were evaluated for color, cooking loss, water uptake, texture analysis profile, and tensile strength. With increasing levels of apple pomace, the whiteness index of the noodles decreased from 77.2 to 54.1 at 0 hr, cohesiveness reduced from 70% to 46%, tensile strength reduced from 47 g to 30 g, while cooking loss increased from 4% to 6.4% and water uptake increased from 67% to 77%. Apple pomace did not affect the hardness and adhesiveness of noodles, but affected the gumminess, chewiness, and springiness to different extents. Overall, 5% to 10% apple pomace levels appeared to be most viable for refined Chinese raw noodles.

Practical applications

This study shows the promising potential of apple pomace as a fiber-enriched alternative to refined noodles. The apple pomace addition alters the quality and textural analysis of Chinese raw noodles.

1 | INTRODUCTION

Food waste is a global problem, and it has been reported that more than one billion dollars of food are wasted each year in the developed economies of the world (Melikoglu, Lin, & Webb, 2013). Thus, more attention has been paid to upcycle, or to find new uses for food processing by-product streams, to develop value-added products with a goal of minimizing the overall amount of food waste and increasing the economic value of food by-products. Traditionally, animal feed has been an effective route for by-product management due to the generally high nutritional quality of by-product streams (Lin et al., 2013). More recently, interest has been expressed in adding these food by-product streams to human food for nutritional improvement and associated health benefits. For example, spent grains from the fermentation of alcoholic beverages are enriched with proteins, fiber, and micronutrients, and can serve as a source of prebiotics. They have been successfully incorporated into chips,

snack bars, and other baked goods to provide prebiotic benefits as an alternative to being discarded as waste (Buss, 2019). For example, vegetable or fruit pomace has been incorporated into bakery goods for improving functional and nutritional qualities including, berry pomace in cakes (Quiles et al., 2018), mushroom and carrot added to muffins (Olawuyi & Lee, 2019), and pear pomace incorporated in layer and sponge cakes (Rocha-Parra, Belorio, Ribotta, Ferrero, & Gómez, 2019). Previously, grape pomace has been extensively investigated and Bordiga, Travaglia, and Locatelli (2019) has summarized the composition and application in a comprehensive review.

The demand for such types of healthy foods worldwide is increasing due to their association with reduced risks from many chronic diseases, such as obesity, diabetes, cardiovascular disease, and high blood pressure levels (Xu, Wang, & Li, 2019). Apple pomace, the primary by-product of apple juice and cider processing, is a good dietary source of fiber with potentially functional ingredients and numerous applications for bakery products (Mir, Bosco, Shah,

Santhalakshmy, & Mir, 2015; Sudha, Baskaran, & Leelavathi, 2006). Apple pomace typically consists of 1.2%–10.8% of moisture, 0.5%–1.9% of ash, 2.4%–7.3% of protein, 1.6%–4.5% of fat, and 51.1%–89.8% of total dietary fiber which includes 36.5%–81.6% insoluble fiber and 4.14%–14.6% soluble fiber (Chen, Rubenthaler, Leung, & Baranowski, 1988; Sudha et al., 2006). In addition, the polyphenols in apple pomace have been reported to be beneficial in reducing the risks of certain chronic diseases such as hypercholesterolemia and certain types of cancer (O'Shea, Arendt, & Gallagher, 2012). Previously, Sudha et al. (2006) demonstrated that apple pomace addition improved the total dietary fiber of cakes from 0.47% (0% addition) to 14.2% (25% of apple pomace addition). In addition, 25% of apple pomace addition to cakes increased 6-folds of total phenolic content in contrast to the control treatment without apple pomace addition (Sudha et al., 2006).

Noodles have been consumed as a staple food from ancient times in most Asian countries. Asian noodles are generally made from flours such as wheat, rice, and other cereals, or grain-based starch. Classifications of noodles can be based on different standards such as, ingredients (wheat or non-wheat noodles); salt composition (presence or absence of alkaline salts, mainly Na_2CO_3 and/or K_2CO_3); manufacturing processes (fresh, semi-dried, dried, instant, steamed, etc.); and noodle size (rectangle or square cross-section) (Arendt & Zannini, 2013). Asian noodle processing consists of mixing raw materials to form an agglomerate-type dough followed by a resting period, sheeting or compounding the dough to form a dough sheet, gradual reduction of the dough sheet thickness, and slitting the final dough sheet into noodle strands (Hou, Otsubo, Okusu, & Shen, 2010). Chinese and Japanese noodles, pastas, and spaghetti are popularly consumed in the U.S. market (Chung, Lee, & Cho, 2010). With consumer demand for healthy foods, noodles have attracted more attention as a potential and popular food item to fortify with fiber. To this end, a few previous studies focused on noodles with apple pomace, including apple pomace incorporated into wheat noodles (Hong, Kim, Yoon, Ryu, & Kim, 1993; Suman & Gupta, 2015), apple pomace added to ramen noodles (Baek, Huh, Huh, & Jung, 2001), and apple fiber incorporated into Turkish homemade noodles (Yüksel & Gurbuz, 2019).

However, to date, there is no report available about incorporation of apple pomace into Chinese raw noodles. Thus, this study focused on fortifying Chinese raw noodles with apple pomace (5%, 10%, 15%, and 20% fwb), and evaluated the fortified noodles with respect to color, cooking loss, water uptake, texture profile analysis, and tensile strength of noodles.

2 | MATERIALS AND METHODS

2.1 | Raw materials

Commercial hard red winter wheat flour was sourced from Grain Craft (protein content, 14% moisture basis, mb: 10.2%), and vital

TABLE 1 Values of wheat flour from Farinograph

Moisture content	12.95
Water absorption (correct to 14.0%)	60.4%
Dough development time	4.0 min
Dough stability	5.2 min
Tolerance index (MTI)	45 BU
Time to breakdown	6.9 min

wheat gluten was purchased from ADM (protein content, 14% mb: 80%). Water absorption, dough development time, dough stability, mixing tolerance index (MTI), and time to breakdown were determined with a Farinograph-E (C.W. Brabender Instruments, Hackensack, NJ) and are shown in Table 1.

2.2 | Apple pomace

Apple pomace was supplied by Hood River Juice Company (Hood River, OR). The apple pomace was received in a frozen state to preserve freshness and was dried prior to use in this study in a forced-air convection oven (Rational USA, Rolling Meadows, IL) overnight at 60°C. The final moisture of the apple pomace after drying was 4.8%. Dried apple pomace was ground into a powder using a Laboratory Mill 3100 (Perten Instruments, Springfield, IL) equipped with a 0.88 mm screen and stored in a sealed plastic bag until use.

2.3 | Noodle preparation

Chinese raw noodles were produced with a pilot-scale noodle processing line (Tokyo Menki Co., Tokyo, Japan). The control noodle formulation (expressed in flour weight basis, fwb) included 100% of flour, 28% of water, and 1.2% of salt. The apple pomace was added into the noodle formulation at 5%, 10%, 15%, and 20% (fwb) along with vital wheat gluten at 2.7% (fwb) to offset the dilution of gluten by the apple pomace. The formula water (fwb) of noodles with apple pomace was adjusted according to the amount of apple pomace in the blend: 28% (control), 32% (5% pomace addition), 36% (10% pomace addition), 40% (15% pomace addition), and 42% (20% pomace addition). The wheat flour, apple pomace, and wheat gluten were weighed and premixed using a Hobart mixer (Model: N-50, Troy, OH) at low speed for 3 min. The subsequent noodle making process is detailed in Figure 1.

2.4 | Color measurement

A section of the noodle sheet was taken immediately prior to cutting for color measurement with a color meter (CR-410, Konica Minolta Sensing Inc., Japan). The same noodle sheet sample was sealed in a

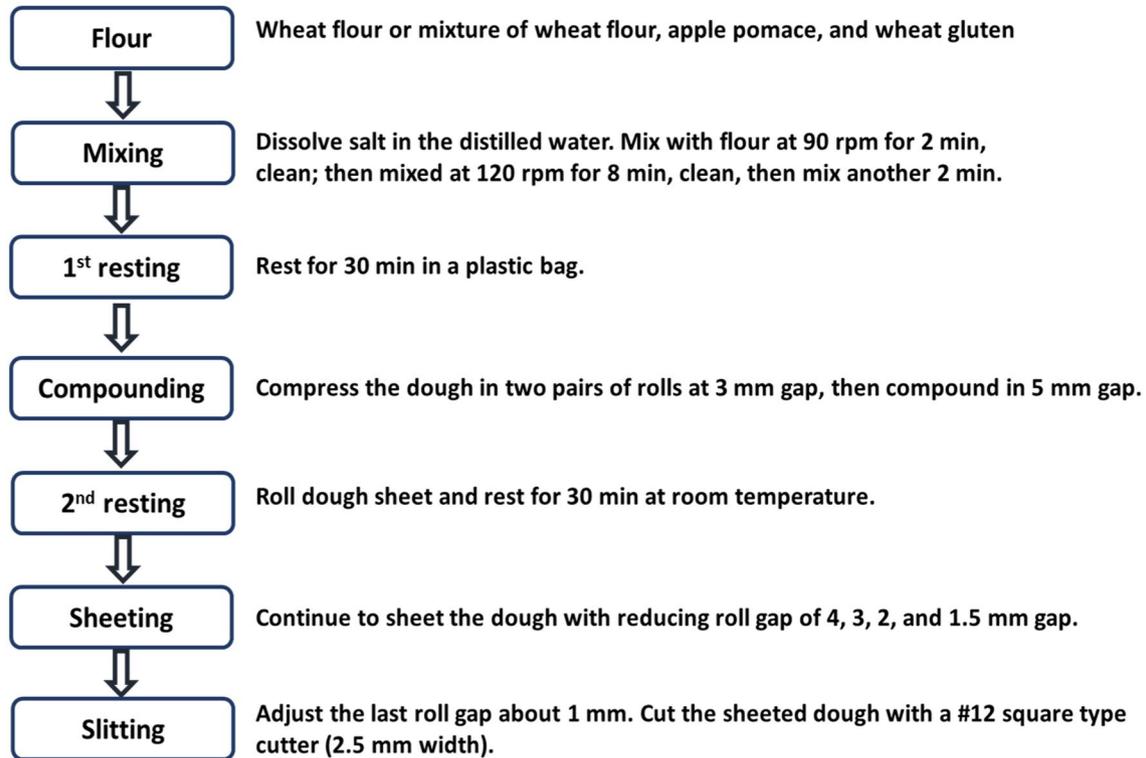


FIGURE 1 Flow chart of noodle processing

plastic bag for subsequent color analysis at 24 hr postprocessing. The L , a , and b values were recorded for each time point.

Whiteness index was also calculated based on the following equation:

$$W = \sqrt{100 - [(100 - L)]^2 + (a^2 + b^2)}$$

where L , a , and b refer to coordinates in color difference L , a , and b .

2.5 | Noodle cooking quality

2.5.1 | Cooking loss

Cooking loss is defined as the amount of noodle solids that dissolve in the cooking water during the cooking step of noodle preparation. The cooking loss was determined using the method described by Liu (2009) with the following modifications: 25 g of noodles were cooked in 300 ml of distilled water in a cooking pot for 1 min until the central opaque core in the noodle strand disappeared. The cooking water was transferred to a preweighed beaker and the water evaporated in a forced-air convection oven (Rational USA, Rolling Meadows, IL) overnight at 100°C. The beaker was then reweighed to capture the weight of the residual solids with final cooking loss calculated using the following formula:

$$\text{Cooking loss (\%)} = \frac{\text{dried residue in cooking water}}{\text{noodle weight before cooking}} \times 100.$$

2.5.2 | Water uptake

Water uptake (%) is measured as the weight ratio of cooked noodles to uncooked noodles, expressed as the percentage of weight of uncooked noodles, and indicates the amount of water absorbed by the noodles during cooking. About 30 g uncooked noodles were boiled until fully cooked for the measurement. Cooked noodles were rinsed with 27°C water and drained for 30 s before weighing. The water uptake was calculated according to the following formula:

$$\text{Water uptake} = \frac{\text{weight of cooked noodles}}{\text{weight of uncooked noodles}} \times 100.$$

2.5.3 | Texture profile analysis

Cooked noodle texture was assessed with a TA-XT2 texture analyzer (Texture Technologies, Hamilton, MA). Prior to analysis, 100 g of noodles were cooked for 1 min in 1 L of boiling deionized water. The noodles were drained and rinsed in 27°C tap water for 10 s with slow stirring. The noodles were transferred to a bowl and covered with a wet paper towel, with all texture measurements completed within 4 min. Five noodle strands (7 cm length) were randomly selected for measurement. A 5 mm thick flat probe was used to conduct a texture profile analysis of the noodles. Testing parameters were set up including: force unit (g), distance format (strain), pretest speed (4 mm/s), test speed (1 mm/s), posttest speed (10 mm/s), strain (70%), time (1 min), and trigger force (20 g). Four replicates were performed for each treatment with all data analyzed using Exponent software.

TABLE 2 *L*, *a*, and *b* values of noodles with different apple pomace addition levels at 0 and 24 hr postprocessing

Apple pomace addition (%)	0 hr			24 hr		
	<i>L</i>	<i>a</i>	<i>b</i>	<i>L</i>	<i>a</i>	<i>b</i>
0	82.1 ± 0.5 ^a	1.4 ± 0.1 ^e	17.1 ± 0.8 ^d	73.0 ± 0.6 ^a	1.5 ± 0.1 ^d	16.7 ± 0.8 ^d
5	71.4 ± 0.3 ^b	5.1 ± 0.1 ^d	19.8 ± 0.3 ^c	64.9 ± 0.2 ^b	6.2 ± 0.1 ^c	22.7 ± 0.3 ^b
10	70.3 ± 0.1 ^c	6.1 ± 0.1 ^c	21.5 ± 0.3 ^b	53.5 ± 0.2 ^c	6.8 ± 0.1 ^c	20.7 ± 0.3 ^c
15	62.1 ± 0.3 ^d	8.0 ± 0.1 ^a	23.7 ± 0.5 ^a	55.9 ± 0.2 ^d	9.7 ± 0.1 ^a	25.7 ± 0.6 ^a
20	61.5 ± 0.5 ^d	7.7 ± 0.2 ^b	23.9 ± 0.4 ^a	57.1 ± 0.8 ^e	9.0 ± 0.4 ^b	25.0 ± 0.4 ^a

Note: *N* = 6. Values are expressed as mean ± standard deviation. Means in the same column with different superscripts are significantly different ($\alpha < .05$) between different apple pomace levels.

2.5.4 | Tensile strength of noodles

Noodles were boiled using the same method described in Section 2.5.3. The tensile strength of noodles was tested using a TA-XT2 texture analyzer equipped with a Kieffer dough rig with the test mode set to tension. One straight noodle strand (7 cm length) was used per replicate. Each noodle strand was placed on the Kieffer platform and pulled with a hook until breakage. Test parameters were set up as: test speed (3 mm/s), target mode (distance), and distance (80 mm). Four replicates were completed for each treatment with the data analyzed using Exponent software.

2.6 | Statistical analysis

Analysis of variance (ANOVA) was performed using Statistical Analysis System (SAS) version 9.4. Data are presented as mean ± standard deviation. Tukey's test was applied to compare the means ($\alpha = .05$).

3 | RESULTS AND DISCUSSION

3.1 | Color measurement of noodles

Color is one of the most important attributes for acceptability of foods due to its effect on consumer expectations for food freshness and flavor, and it is especially important for consumer acceptance of noodles. Color and appearance are important noodle qualities as a result of interplay between ingredients and processing (Fuerst, Anderson, & Morries, 2010). Color measurements including *L* (light/dark), *a* (green/blue), and *b* (red/yellow) values of noodles with different apple pomace levels in this study are shown in Table 2. The whiteness index was calculated and is displayed in Table 3. Images of noodles with different apple pomace addition stored for 24 hr are shown in Figure 2.

From Table 2, whether at 0 or 24 hr, increasing the amount of apple pomace in the noodles resulted in decreasing *L* values, indicating increased darkness of noodles. Similarly, the greenness and

TABLE 3 Whiteness index of noodles with different apple pomace addition levels at 0 and 24 hr postprocessing

Whiteness index		
Apple pomace addition (%)	0 hr	24 hr
0	77.15 ± 0.84 ^{aA}	68.16 ± 0.90 ^{aB}
5	64.85 ± 0.40 ^{bA}	57.75 ± 0.32 ^{bB}
10	62.84 ± 0.50 ^{cA}	48.67 ± 0.09 ^{cdB}
15	54.60 ± 0.50 ^{dA}	48.03 ± 0.36 ^{cdB}
20	54.11 ± 0.62 ^{dA}	49.59 ± 0.97 ^{dB}

Note: *N* = 6. Values are expressed as mean ± standard deviation. Means in the same column with different lower-case superscripts are significantly different ($\alpha < .05$) between apple pomace levels. Means in the same row with different upper-case superscripts are significantly different ($\alpha < .05$) between 0 and 24 hr postprocessing.

yellowness of noodles increased with apple pomace addition at 0 and 24 hr, respectively. From Table 3, the whiteness index was also compared among the different treatments at 0 or 24 hr, respectively. A creamy white color is preferred in Asian noodles (Crosbie & Ross, 2004). Greater amounts of apple pomace resulted in a significant reduction of the whiteness index of noodles in contrast to the control noodle at both 0 and 24 hr. When compared within the same treatments, the 24 hr storage period resulted in lower whiteness index values of noodles compared to that immediately postprocessing (0 hr).

The change of color was primarily due to the naturally occurring polyphenol oxidase (PPO) found in both apple pomace and wheat flour. PPO is the catalyst of the enzymatic browning reaction and triggers the generation of dark pigments in fruits and vegetables. In apples, phenolics such as catechin, epicatechin, and chlorogenic acid are the substrates for PPO, and oxidation results in the browning of apples after cutting (Rocha & Morais, 2001). In mature apples, PPO activity has been reported to range from 69.2 to 1,307.9 (units/100 g fresh weight) depending on the apple variety (Holderbaum, Kon, Kudo, & Guerra, 2010). In contrast to apples, comparatively low PPO activity exists in wheat, which was reported to be around 1 AU depending on wheat variety (Onto, 2011).



FIGURE 2 Images of noodles stored for 24 hr. (a) Control. (b) 5% apple pomace addition. (c) 10% apple pomace addition. (d) 15% apple pomace addition. (e) 20% apple pomace addition

3.2 | Cooking loss and water uptake of noodles

Cooking loss is an important indicator of noodle quality due to its relationship to final weight, portion size, perceived juiciness (the oral sensation of water exudation from the product on biting or chewing), and the final product eating texture. In this study, cooking loss increased slightly with increases in apple pomace addition levels, ranging from 4% (control) to 6.4% (20% wt/wt of apple pomace) (shown in Table 4). During boiling, starch granules in the noodle will absorb water, swell, and gelatinize. Delcour et al. (2012) demonstrated that cooling loss of pasta is caused by excessive starch swelling, however, can be prevented by the protein due to the competition for water, indicating protein can restrict starch swelling in the pasta. In our study, the addition of wheat gluten increased with increasing apple pomace addition. Therefore, a slight increase of cooking loss was observed from 4% (control) to 6.4% (20% wt/wt of apple pomace addition). According to Giuberti, Gallo, Cerioli, Fortunati, and Masoero (2015), the quality of noodles will be reduced when the cooking loss exceeds 12%. It has also been reported that cooking loss for good quality pasta should be lower than 12% (Hoseney, 1994). In this study, we observed low

TABLE 4 Cooking loss and water uptake of noodles with different apple pomace addition

Apple pomace addition (%)	Cooking loss (%)	Water uptake (%)
0	4.0 ± 0.0 ^b	67.0 ± 0.5 ^e
5	5.2 ± 0.6 ^{ab}	69.8 ± 0.2 ^d
10	5.6 ± 0.0 ^a	72.5 ± 0.2 ^c
15	5.6 ± 0.0 ^a	74.0 ± 0.9 ^b
20	6.4 ± 0.6 ^a	77.1 ± 0.7 ^a

Note: $N = 2$. Values are expressed as mean ± standard deviation. Different superscripts in the same column are significantly different ($\alpha < .05$).

cooking loss from noodles with apple pomace addition, indicating that the addition of apple pomace does not adversely affect the noodle cooking quality.

In terms of water uptake, the 20% of apple pomace treatment showed the greatest ability to retain water in noodles. In our research, the naturally high dietary fiber content of apple pomace contributed to this increased water uptake, and the water uptake increased in line with apple pomace addition levels. For example,

it has been reported that the water absorbing capacity of apple pomace has been reported to be 2.5 ml/g (Rocha-Parra, Ribotta, & Ferrero, 2015), indicating increasing apple pomace addition levels resulted in increasing water uptake of noodles. Starch and apple pomace at the surface of the noodle are capable of absorbing their full capacity for water, while the interior is not directly exposed to the water, relying instead on diffusion (Rocha-Parra et al., 2015). In addition, the protein network in the noodle limits swelling and expansion of starch and apple pomace, therefore, further limiting their ability to maximally absorb water. Consequently, the water uptake of noodles with increased apple pomace addition will increase, but will not equate to their full water absorption capacity. This finding was in an agreement with research reported by Bock et al. (2015) that wheat bran competed for available water with starch and redistributed available water in the pasta system. The greater water uptake of noodles with added apple pomace also translated to increased cooking yield of noodles. In this study, the cooking yield was calculated using the same formula as water uptake since both are primarily dependent on water absorption of the cooked noodles.

3.3 | Texture profile analysis of noodles

The texture profile analysis of noodles including hardness, adhesiveness, cohesiveness, gumminess, springiness, and chewiness is shown in Table 5. The addition of apple pomace did not result in a significant change in the hardness of noodles compared to the control. Hardness measures a material's resistance to surface deformation. Similarly, adhesiveness was not affected by apple pomace addition. In terms of cohesiveness, apple pomace addition from 5% to 20% reduced the cohesiveness of noodles versus the control. There was no significant difference of gumminess of noodles compared to the control, except, interestingly, for the 15% of apple pomace treatment that exhibited reduced gumminess. Springiness of the noodles was significantly reduced at the 20% of apple pomace addition level. Other addition levels from 5% to 15% did not result in any significant differences in springiness. Chewiness of the noodles showed a similar trend to the gumminess in that only the 15% addition level of apple pomace significantly decreased the chewiness.

Apple pomace addition in starch-based formulations can potentially not only increase the dietary fiber level, but it also affects the microstructure of starch-based systems (Rocha-Parra et al., 2015). Rocha-Parra et al. (2015) found that apple pomace exhibited a stronger water absorbing capacity than starch, and thus, by absorbing more water it delayed starch gelatinization and affected pasting properties. In addition, Rocha-Parra et al. (2015) demonstrated that apple pomace addition also influenced structural changes during storage. Taken together, similar microstructural changes likely occurred in the noodles enriched with apple pomace in this study and affected the textural changes. However, this study did not pursue any microscopy or other structural elucidation of the final noodles to correlate with textural results. Thus, more research and studies are recommended to focus on

TABLE 5 Texture profile of noodles with different apple pomace addition

Apple pomace addition (%)	Hardness (g)	Adhesiveness (g*s)	Springiness	Cohesiveness (%)	Gumminess	Chewiness	Tensile strength (g)
0	1,042.22 ± 76.32 ^c	-25.68 ± 4.87 ^a	0.96 ± 0.02 ^a	0.70 ± 0.01 ^a	728.97 ± 61.16 ^a	701.81 ± 68.68 ^a	47.39 ± 4.35 ^a
5	1,410.15 ± 187.77 ^b	-46.13 ± 14.93 ^a	0.95 ± 0.01 ^{ab}	0.46 ± 0.03 ^b	658.26 ± 127.06 ^{ab}	627.09 ± 120.58 ^{ab}	38.18 ± 2.35 ^b
10	1,526.52 ± 198.24 ^b	-40.39 ± 2.60 ^a	0.95 ± 0.01 ^{ab}	0.46 ± 0.04 ^b	712.76 ± 154.19 ^{ab}	673.53 ± 142.00 ^{ab}	32.12 ± 3.08 ^b
15	1,505.66 ± 51.24 ^b	-50.01 ± 12.67 ^a	0.94 ± 0.01 ^{ab}	0.46 ± 0.03 ^b	598.89 ± 169.18 ^b	565.01 ± 156.57 ^b	33.00 ± 4.35 ^b
20	2,045.42 ± 314.71 ^a	-52.02 ± 20.38 ^a	0.93 ± 0.03 ^b	0.47 ± 0.07 ^b	968.70 ± 220.75 ^{ab}	900.40 ± 223.98 ^{ab}	31.44 ± 5.71 ^b

Note: N = 4. Values are expressed as mean ± standard deviation. Means in the same column with different lower-case superscripts are significantly different ($\alpha < .05$) between apple pomace levels.

the effect of fiber addition on texture, especially as impacted by any changes in the microstructure of noodles.

3.4 | Tensile strength of noodles

The tensile strength of the noodles is shown in Table 5. Tensile strength measures how much stress can be applied to an element before it fractures or breaks down. Apple pomace addition levels from 5% to 20% reduced the tensile strength of noodles compared to the control treatment. The tensile strength of noodles mainly relies on the network of gluten protein and rigid nature of fiber (Shiau, Wu, & Liu, 2011). The cooking process resulted in starch gelatinization and protein denaturation. Thus, when combined with the gluten disrupting presence of the apple pomace, these phenomena result in the overall softening of the noodles and loss of tensile strength in comparison to the control.

4 | CONCLUSION

This is the first study to explore the addition of apple pomace to Chinese raw noodles. Tests were conducted to evaluate the color, cooking quality, texture profile analysis, and tensile strength of apple pomace enriched noodles. The final results showed that apple pomace addition reduced the whiteness index of noodles, increased the cooking loss and water uptake, and reduced the tensile strength of noodles. Apple pomace addition also affected the texture profile of the noodles. However, the degree of influence was dependent on the particular textural parameter. All textural parameters were not affected to the same extent. However, the microstructural properties of the noodles were not explored in this study, thus, the mechanistic role of apple pomace in the textural properties of noodles warrants additional research.

Overall, the cooking quality and textural properties were within an acceptable range across most apple pomace addition levels, suggesting the potential to introduce similar enriched products into commercial markets. The biggest barrier to adoption of these noodles, however, is likely to be the dark color of the noodles. Treatments of 5% to 10% apple pomace addition are more likely to be attractive because of the lighter appearance relative to 15% and 20% apple pomace levels. In future, sensory analysis of noodles with different apple pomace addition seems warranted since sensory property of noodles will influence the consumption for consumers. Sensory analysis can be evaluated in terms of appearance, color, taste, texture, and overall acceptability.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

ORCID

Jingwen Xu  <https://orcid.org/0000-0003-2625-8440>

REFERENCES

- Arendt, E. K., & Zannini, E. (2013). Wheat and other Triticum grains. *Cereal Grains for the Food and Beverage Industries* (1–66). Cambridge, UK: Woodhead Publishing Ltd.
- Baek, Y. J., Huh, C. S., Huh, J. G., & Jung, H. R. (2001). Method for producing ramen of which acidification is retarded by using apple pomace dietary fibre. *Korea Yakult*, 12, 653–659.
- Bock, J. E., West, R., Iametti, S., Bonomi, F., Marengo, M., & Seetharaman, K. (2015). Gluten structural evolution during pasta processing of refined and whole wheat pasta from hard white winter wheat: The influence of mixing, drying, and cooking. *Cereal Chemistry*, 92(5), 460–465. <https://doi.org/10.1094/CCHEM-07-14-0152-R>
- Bordiga, M., Travaglia, F., & Locatelli, M. (2019). Valorisation of grape pomace: An approach that is increasingly reaching its maturity—A review. *International Journal of Food Science & Technology*, 54(4), 933–942. <https://doi.org/10.1111/ijfs.14118>
- Buss, D. (2019). Closing the loop on food waste. *Food Technology*, 73(1), 20–29.
- Chen, H., Rubenthaler, G. L., Leung, H. K., & Baranowski, J. D. (1988). Chemical, physical, and baking properties of apple fiber compared with wheat and oat bran. *Cereal Chemistry*, 65(3), 244–247.
- Chung, C. E., Lee, K. W., & Cho, M. S. (2010). Noodle consumption patterns of American consumers: Nhanes 2001–2002. *Nutrition Research and Practice*, 4(3), 243–251. <https://doi.org/10.4162/nrp.2010.4.3.243>
- Crosbie, G. B., & Ross, A. S. (2004). Noodles | Asian wheat flour noodles. In C. Wrigley (Ed.), *Encyclopedia of grain science* (pp. 304–312). Cambridge, USA: Academic Press, Elsevier Ltd.
- Delcour, J. A., Joye, I. J., Pareyt, B., Wilderjans, E., Brijs, K., & Lagrain, B. (2012). Wheat gluten functionality as a quality determinant in cereal-based food products. *Annual Review of Food Science and Technology*, 3, 469–492. <https://doi.org/10.1146/annurev-food-022811-101303>
- Fuerst, E. P., Anderson, J. V., & Morris, C. F. (2010). Effects of polyphenol oxidase on noodle color: Mechanisms, measurement, and improvement. In G. Hou (Ed.), *Asian noodles: Science, technology, and processing* (pp. 99–140). Hoboken, NJ: John Wiley & Sons Inc.
- Giuberti, G., Gallo, A., Cerioli, C., Fortunati, P., & Masoero, F. (2015). Cooking quality and starch digestibility of gluten free pasta using new bean flour. *Food Chemistry*, 175, 43–49. <https://doi.org/10.1016/j.foodchem.2014.11.127>
- Holderbaum, D. F., Kon, T., Kudo, T., & Guerra, M. P. (2010). Enzymatic browning, oxidase activity, and polyphenols in four apple cultivars: Dynamics during fruit development. *Horticultural Science*, 4(8), 1150–1154.
- Hong, J. S., Kim, M. K., Yoon, S., Ryu, K. S., & Kim, Y. K. (1993). Preparation of noodle supplemented with treated apple pomace and soymilk residue as a source of dietary fibre. *Journal of Korean Agricultural Chemical Society*, 36(2), 80–85.
- Hoseney, C. (1994). Principles of cereal science and technology. 2nd ed. *American Association of Cereal Chemists* (269–274). St. Paul, USA: American Association of Cereal Chemists, Inc.
- Hou, G., Otsubo, S., Okusu, H., & Shen, L. (2010). Noodle processing technology. In G. Hou (Ed.), *Asian noodles: Science, technology, and processing* (pp. 99–140). Hoboken, NJ: John Wiley & Sons Inc.
- Lin, C. S. K., Pfaltzgraff, L. A., Herrero-Davila, L., Mubofu, E. B., Abderrahim, S., Clark, J. H., ... Thankappan, S. (2013). Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. *Energy & Environmental Science*, 6(2), 426–464.
- Liu, L. (2009). *Evaluation of four sorghum hybrids in a gluten-free noodle system*, Master thesis. Manhattan, KS: Kansas State University.
- Melikoglu, M., Lin, C., & Webb, C. (2013). Analysing global food waste problem: Pinpointing the facts and estimating the energy content. *Open Engineering*, 3(2), 157–164. <https://doi.org/10.2478/s13531-012-0058-5>

- Mir, S. A., Bosco, S. J. D., Shah, M. A., Santhalakshmy, S., & Mir, M. M. (2015). Effect of apple pomace on quality characteristics of brown rice based cracker. *Journal of the Saudi Society of Agricultural Sciences*, 16(1), 25–32. <https://doi.org/10.1016/j.jssas.2015.01.001>
- O'Shea, N., Arendt, E. K., & Gallagher, E. (2012). Dietary fibre and phytochemical characteristics of fruit and vegetable by-products and their recent applications as novel ingredients in food products. *Innovative Food Science & Emerging Technologies*, 16, 1–10.
- Olawuyi, I. F., & Lee, W. Y. (2019). Quality and antioxidant properties of functional rice muffins enriched with shiitake mushroom and carrot pomace. *International Journal of Food Science & Technology*, 54(7), 2321–2328. <https://doi.org/10.1111/ijfs.14155>
- Onto, S. (2011). Genetics of polyphenol oxidase (PPO) activity in wheat (*Triticum aestivum* L.). PhD dissertation. Lincoln, NE: University of Nebraska-Lincoln.
- Quiles, A., Llorca, E., Schmidt, C., Reißner, A. M., Struck, S., Rohm, H., & Hernando, I. (2018). Use of berry pomace to replace flour, fat or sugar in cakes. *International Journal of Food Science & Technology*, 53(6), 1579–1587. <https://doi.org/10.1111/ijfs.13765>
- Rocha, A. M. C. N., & Morais, A. M. M. B. (2001). Characterization of polyphenoloxidase (PPO) extracted from "Jonagored" apple. *Food Control*, 12(2), 85–90. [https://doi.org/10.1016/S0956-7135\(00\)00026-8](https://doi.org/10.1016/S0956-7135(00)00026-8)
- Rocha-Parra, A. F., Belorio, M., Ribotta, P. D., Ferrero, C., & Gómez, M. (2019). Effect of the particle size of pear pomace on the quality of enriched layer and sponge cakes. *International Journal of Food Science & Technology*, 54(4), 1265–1275. <https://doi.org/10.1111/ijfs.14078>
- Rocha-Parra, A. F., Ribotta, P. D., & Ferrero, C. (2015). Starch-apple pomace mixtures: Pasting properties and microstructure. *Food and Bioprocess Technology*, 8(9), 1854–1863. <https://doi.org/10.1007/s11947-015-1541-9>
- Shiau, S. Y., Wu, T. T., & Liu, Y. L. (2011). Effect of the amount and particle size of wheat fiber on textural and rheological properties of raw, dried and cooked noodles. *Journal of Food Quality*, 35(3), 207–216. <https://doi.org/10.1111/j.1745-4557.2012.00436.x>
- Sudha, M. L., Baskaran, V., & Leelavathi, K. (2006). Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. *Food Chemistry*, 104(2), 686–692. <https://doi.org/10.1016/j.foodchem.2006.12.016>
- Suman, Y., & Gupta, R. K. (2015). Formulation of noodles using apple pomace and evaluation of its phytochemicals and antioxidant activity. *Journal of Pharmacognosy and Phytochemistry*, 4(1), 99–106.
- Xu, J., Wang, W., & Li, Y. (2019). Dough properties, bread quality, and associated interactions with added phenolic compounds: A review. *Journal of Functional Foods*, 52, 629–639. <https://doi.org/10.1016/j.jff.2018.11.052>
- Yuksel, F., & Gurbuz, M. (2019). Physicochemical, textural, cooking and sensory properties of traditional Turkish homemade noodle enriched with apple fiber. *AkademikGıda*, 17(1), 16–22.

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