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RESEARCH NOTE

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Textural Improvement of Sweet Potato Starch Noodles Prepared without Freezing Using Gums and Other Starches

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Abstract Sweet potato starch noodles prepared without freezing exhibited higher cooking loss and water uptake during cooking and usually resulted in noodles with a softer and stickier texture compared to commercial sweet potato starch noodles manufactured using a freezing process. By utilizing the starches of different plant sources (potato, cowpea, and sago in an equivalent mixture with sweet potato starch), however, the cooking properties and texture of the starch noodles could be improved. Among the starches tested, cowpea starch was most effective in providing cooking and textural properties similar to those of commercial noodles. As an alternative approach, the addition of a minor amount (0.1% based on total solid weight) of various gums (xanthan, gellan, locust bean gum, curdlan, and carboxymethyl cellulose) was also examined. The addition of curdlan to noodles was effective in increasing the gumminess and hardness, and reducing the stickiness of noodles. Utilizing different starches and gums can improve the overall texture and quality of sweet potato starch noodles produced without freezing.

Keywords: sweet potato starch, noodles, gums, texture

Introduction

Sweet potato starch is used routinely in the production of starch noodles in many Asian countries, however sweet potato starch is expensive in comparison to other popular bulk starches, including corn, potato, and wheat starches. Therefore, potato starch is used as a raw material in some noodle products in Japan, and the resulting noodles have been reported to have a neutral taste, and a high degree of transparency and flexibility (1). In the preparation of a Korean starch gel dish known as *'muk'*, mungbean starch was traditionally used as a raw material (2). Because the starch is very expensive, however, cowpea starch is currently used as a substitute. The use of cowpea starch results in the formation of a hard and cohesive gel (3). However, the utilization of cowpea starch in the production of starch noodles has not been adequately explored.

In the traditional process used for the manufacture of starch noodles, a starch slurry is dropped into boiling water which rapidly cooks forming noodle strands. These strands are then subjected to freezing and thawing, thus rendering the noodles chewy and elastic. However, a starch noodle product called '*kuzukiri*' is commercially manufactured in Japan without such a freezing process (4). During this process, a thin sheet of starch gel formed on a steel belt is aged in a refrigerator, cut into starch noodles, and dried in an air oven. This process saves both time and costs, and the noodles produced tend to be straighter than those prepared via conventional methods. Sweet potato starch noodles have been prepared without freezing by following the process for producing '*kuzukiri*' (5). Through an optimization of the process variables, noodles produced without freezing exhibit qualities comparable to those of commercial noodles, but remain softer and stickier.

Non-starch polysaccharides have been used to improve the texture of pasta and instant noodles (6, 7). With the addition of 1 or 2% xanthan, the firmness of pasta can be improved without any adverse effects on either moisture uptake or swelling (6). Guar gum (less than 0.37%) has also been shown to enhance the elasticity and extensibility of cooked instant fried noodles (7).

In the present study, the effects of the partial replacement (50%) of sweet potato starch with various starches and the effects of the addition of a variety of hydrocolloids on the texture of cooked sweet potato starch noodles were examined.

Materials and Methods

Materials Sweet potato starch (17% moisture, isolated from Korean sweet potato) was purchased from the Kwak-Ji Agri-Fishery Co. (Jeju, Korea). Potato starch (Handuk Avebe, Seoul, Korea), cowpea starch (Pulmuone Chanmaru Foods Co. Ltd., Seoul, Korea) and sago starch (Shimada Chemical and Engineering, Tokyo, Japan) were provided as gifts. Xanthan, gellan gum, locust bean gum (LBG), carboxymethyl cellulose (CMC), and curdlan were purchased from the Nutrasweet Kelco Company (San Diego, CA, USA), Kelco Company, MSC Co. Ltd. (Seoul, Korea), Showa Chemical Inc. (Tokyo, Japan), and Takeda Chemical Industries Ltd. (Tokyo, Japan), respectively. A commercial sweet potato starch noodle product (Korean vermicelli), which was manufactured using a freezing process, was purchased from Oddugi, Inc. (Gyeonggi, Korea).

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Starch noodle production The starch noodles were prepared without freezing in accordance with the methods developed by Lee *et al.* (5). In this procedure, a starch gel (44.7% starch solids) was formed into a thin sheet (1.5 mm thickness), aged for 3 or 21 hr at 4°C, then cut into thin noodle strands (2 mm width) with a roller cutter. In the starch blends, sweet potato starch and one of the other starches were mixed at an 1:1 ratio on a dry-weight basis. The tested gums were added to a concentration of 0.1% with regard to total solids. The gums were completely dissolved in warm water (50 °C) before the starch was mixed.

Cooking loss and water uptake The cooking loss and water uptake of starch noodles were analyzed in accordance with the methods described by Takahashi *et al.* (8). The amount of soluble starch during cooking (10 g noodle, 3 min boiling) was measured via the phenol-sulfate method (9), and cooking losses were calculated according to the percent weight of the soluble starch relative to the dry noodle solids. Water uptake was calculated as the percentage of weight increase relative to the dry noodle solids.

Texture analysis The chewiness, gumminess, and hardness of the cooked noodles (3 min boiling) were determined within 5 min after cooking using a texture analyzer (TA-XT2, Stable Micro System, Surrey, UK) in accordance with the procedure described by Lee *et al.* (5). Each of the noodle strands was compressed twice, at a rate of 2.0 mm/sec, using a small flat-faced cylinder probe (20 mm diameter) at a compression ratio of 70%, which did not induce any surface fractures. The elasticity and stickiness of the compressed strands were then measured via sensory evaluation, in accordance with the procedures described by Lee *et al.* (5).

Statistical analysis All data were analyzed using a statistical analysis system (10), and significant differences were determined using Duncan's multiple tests (SAS Institute, Cary, NC, USA).

Results and Discussion

Cooking loss and water uptake The cooking loss and water uptake of starch noodles prepared with various starch blends are provided in Table 1. The noodles of pure sweet potato starch prepared without freezing exhibited higher cooking loss and water uptake than did the commercial sweet potato starch noodles manufactured with the freezing process. This result indicates that the freezing process used in commercial noodle production imparts rigidity and integrity during cooking.

By extending the aging time from 3 to 21 hr, the cooking loss of noodles prepared with pure sweet potato starch was effectively reduced (2.04 to 1.07%), whereas the water uptake was slightly increased (from 3.03 to 3.13%). It was assumed that the degree of starch retrogradation was increased due to extending the aging process, and thus the rigidity of the noodle matrices was increased. When other starches were used, cooking loss and water uptake were reduced (Table 1). The noodles containing the starch blends displayed decreased cooking losses (<0.2%) when the aging time was increased from 3 to 21 hr. The decreases, however, were less than that observed with noodles containing pure sweet potato starch (about 1.0%). This may indicate that the noodles containing starch blends are less susceptible to the aging than the pure sweet potato starch noodles. The differences in water uptake among the noodles of different starch blends were less than those in cooking loss.

Among the starches tested, cowpea starch was most effective in reducing the cooking loss and water uptake to levels similar to those observed with the commercial sweet

Table 1. Cooking loss and water uptake of sweet potato starch noodles blended with other starches (1:1 weight ratio)[1)]

Samples	Cooking loss (%)	Water uptake (g/g)
Commercial[2)]	0.61_d	2.65_f
Sweet potato starch 3[3)]	2.04_a	3.03_b
Sp[4)] + potato	1.76_b	2.71_d
Sp + cowpea	1.21_c	2.75_c
Sp + sago	1.25_c	2.69_e
Sweet potato starch 21[3)]	1.07_c	3.13_a
Sp + potato	1.67_b	2.51_h
Sp + cowpea	1.03_c	2.61_g
Sp + sago	1.14_c	2.71_d

1)Each value represents the mean of triplicates. Data with different letters were significantly different ($p<0.05$).
2)Commercial sweet potato starch noodles.
3)Aging time (hr).
4)Sweet potato starch.

Table 2. Cooking loss and water uptake of sweet potato starch noodles containing various gums (0.1% of total solids)[1)]

Samples	Cooking loss (%)	Water uptake (g/g)
Commercial[2)]	0.61_d	2.65_i
Sweet potato starch 3[3)]	2.04_a	3.03_g
Xanthan	1.17_{bc}	3.29_c
Gellan	1.26_{bc}	3.19_e
Curdlan	1.22_{bc}	3.09_f
CMC[4)]	1.39_{bc}	3.45_a
LBG[5)]	1.14_{bc}	2.66_h
Sweet potato starch 21[3)]	1.07_b	3.13_f
Xanthan	0.98_{bcd}	3.35_b
Gellan	0.97_{cd}	3.38_b
Curdlan	1.05_{bcd}	3.00_{gh}
CMC	1.12_{bc}	3.25_d
LBG	1.13_{bc}	3.26_{cd}

1)Each value represents the mean of triplicates. Data with different letters were significantly different ($p<0.05$).
2)Commercial sweet potato starch noodles.
3)Aging time (hr).
4)Carboxymethylcellulose.
5)Locust bean gum.

potato starch noodles. We attribute this result to the inherent properties of cowpea starch in rigid gel formation (11).

The addition of minor amounts (0.1% of total solids) of a variety of hydrocolloids also exerted some effects on the cooking properties of the sweet potato starch noodles (Table 2). When the noodles were aged for 3 hr, the addition of various gums reduced the cooking loss. By extending the aging period to 21 hr, the cooking loss of noodles containing the gums was further reduced, as with the blended starch noodles. The degree of cooking loss reduction for noodles containing gums, however, was much less than that of pure starch noodles. Among the gums tested, xanthan and LBG were more effective in reducing the cooking loss than other gums when the noodles were aged for 3 hr. When aged for 21 hr, noodles containing xanthan or gellan gum exhibited reduced cooking losses relative to noodles containing other gums (curdlan, CMC, and LBG).

The addition of gums did not reduce the water uptake of starch noodles, except the addition of LGB. This result might be due to the hydrophilic nature of gums. At 3 hr of aging, LGB appeared to be most effective in reducing water uptake to a value (2.66 g/g) comparable to that of commercial noodles, and also resulted in the lowest level of cooking loss (1.14%) among the gums (Table 2). When noodles were aged for 21 hr, however, the curdlan noodles showed the least water uptake (3.00 g/g), and a relatively low level of cooking loss (1.05%). It has been reported that aqueous solutions of both LGB and curdlan readily form gels (12, 13). Curdlan, in particular, favors thermal treatment in gelling (13). Although the amount of each gum added to the noodles was very small, the gelling tendencies of both gums might facilitate the formation of stable matrices in starch noodles. It is also likely that gum molecules associated with starch chains, which might play a key role in the formation of noodle matrices.

Texture analysis The textural properties of noodles made from various starch blends are provided in Table 3. In our previous study, it was found that sweet potato starch noodles prepared without freezing were softer and stickier compared to commercial noodles (5). By extending the aging time from 3 to 21 hr, the hardness of noodles, as determined mechanically, increased, and the stickiness measured by sensory analysis decreased. However, no statistical significance in the differences was found. The blending of sweet potato starch and other starches resulted in increased chewiness, gumminess, and hardness of the cooked noodles. However, changes in the elasticity and stickiness of the noodles, which were determined by sensory panels, were not statistically significant. As indicated in the cooking test (Table 1), the noodles of blended starches formed more stable noodle matrices than the pure sweet potato starch noodles, providing a more rigid and firm texture (Table 3). Among the substitute starches tested, cowpea starch had the most significant effects on noodle texture resulting in the highest values for chewiness (1682.03 g), gumminess (1725.98 g), and hardness (1932.35 g) when the noodles were aged for 21 hr. Chung *et al.* (11) compared the gel texture of different starches, and reported that cowpea starch gel was both harder and chewier than either corn or potato starch gels. Noodles containing potato or cowpea starch showed relatively lower values of stickiness (4.50 and 3.29, respectively), which were statistically comparable to those of commercial noodles (3.79). However, those noodles remained harder and chewier than the commercial noodles. The textural properties of starch noodles containing added gums are shown in Table 4. The textural qualities of noodles depended on the gum added ($p<0.05$). All gums except xanthan increased noodle chewiness, gumminess, and hardness. However, the increases were much less than those associated with the noodles of blended starches (Table 3). Xanthan is normally used as a thickener, and does not form a gel by itself, whereas curdlan tends to form a gel when heated in an aqueous dispersion (13, 14). Noodles containing curdlan and aged for 3 hr exhibited the highest textural values, and were comparable to those of commercial noodles. Noodles containing curdlan also exhibited the least degree of stickiness among the gum-containing noodles, and were rated the most acceptable by sensory panels (data not shown). Since the starch noodles had been cooked, we

Table 3. Textural properties of sweet potato starch noodles blended with other starches (1:1 weight ratio)[1)]

	Chewiness (g)	Gumminess (g)	Hardness (g)	Elasticity	Stickiness
Commercial[2)]	1054.48_c	1097.41_c	1153.93_c	4.85_a	3.79_b
Sweet potato starch 3[3)]	892.64_c	936.96_c	984.17_c	4.83_a	5.00_{ab}
Sp[4)] + potato	1393.18_b	1470.27_b	1595.23_b	4.86_a	4.50_b
Sp + cowpea	1669.4_a	1714.10_a	1930.40_a	4.86_a	4.17_b
Sp + sago	1304.1_b	1345.09_b	1442.03_b	6.04_a	4.14_b
Sweet potato starch 21[3)]	957.59_c	999.33_c	1016.83_c	4.67_a	4.50_{ab}
Sp + potato	1523.99_{ab}	1565.32_{ab}	1660.63_{ab}	5.17_a	4.50_b
Sp + cowpea	1682.03_a	1725.98_a	1932.35_a	4.83_a	3.29_b
Sp + sago	1382.72_b	1358.27_b	1505.63_b	5.57_a	6.17_a

1)Each value represents the mean of triplicates. Data with different letters were significantly different ($p<0.05$).
2)Commercial sweet potato starch noodles.
3)Aging time (hr).
4)Sweet potato starch.

Table 4. Textural properties of sweet potato starch noodles containing various gums (0.1% of total solids)[1)]

Samples	Chewiness (g)	Gumminess (g)	Hardness (g)	Elasticity	Stickiness
Commercial[2)]	1054.48_{abc}	1097.41_{abc}	1153.93_a	4.64_a	3.38_c
Sweet potato starch 3[3)]	892.64_{cd}	936.96_{bcd}	984.17_{ab}	4.83_a	5.00_{ab}
Xanthan	739.00_d	758.25_d	742.40_b	4.71_a	4.83_{ab}
Gellan	912.55_{bcd}	965.57_{bcd}	1029.80_{ab}	4.86_a	4.67_{abc}
Curdlan	1096.62_{abc}	1162.50_{abc}	1181.62_a	4.83_a	3.83_{bc}
CMC[4)]	993.87_{abc}	1063.68_{abc}	1077.50_a	4.43_a	5.29_a
LBG[5)]	1051.09_{abc}	1090.79_{abc}	1138.28_a	5.00_a	5.67_a
Sweet potato starch 21[3)]	957.59_{abcd}	999.33_{abcd}	1016.83_{ab}	4.67_a	4.50_{abc}
Xanthan	861.39_{cd}	910.57_{cd}	964.90_{ab}	4.83_a	5.43_a
Gellan	1071.46_{abc}	1117.31_{abc}	1189.83_a	5.43_a	4.57_{abc}
Curdlan	1169.75_a	1234.77_a	1278.00_a	5.00_a	4.71_{abc}
CMC	1138.61_{ab}	1181.87_{ab}	1259.50_a	5.57_a	5.43_a
LBG	913.89_{bcd}	971.18_{bcd}	1051.27_{ab}	5.20_a	5.67_a

[1)]Each value represents the mean of triplicates. Data with different letters were significantly different (p<0.05).
[2)]Commercial sweet potato starch noodles.
[3)]Aging time (hr).
[4)]Carboxymethylcellulose.
[5)]Locust bean gum.

assumed that the noodle network was reinforced due to the gelling tendency of curdlan.

The results of the present study reveal that both blending with different starches and incorporating gums into sweet potato starch noodles can effectively improve the cooking quality and texture of noodles prepared without freezing, resulting in textural values comparable to those of the commercial sweet potato starch noodles. However, more studies are necessary in order to optimize these effects, possibly by changing the amounts of the blended starches and gums, and by utilizing both starch blends and gums together.

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