Effect of phosphate salts on the Korean non-fried instant noodle quality

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Abstract

As consumers worldwide are concerned about health issues, the demand for non-fried instant noodle has increased rapidly in recent years. Korean instant noodle typically contains a high level of modified starch, especially modified potato starch such as acetylated potato starch (APS), for its unique eating quality. This often leads to high material cost. The objective of this research was to investigate the effect of three phosphate salts (PS) on the quality of Korean non-fried instant noodle made with reduced level of APS. The results showed that PS and APS had similar effects on noodle quality. All PS gave noodle a brighter and yellower appearance. Reducing APS level from 15% to 10% resulted in a much harder noodle, but adding PS into noodles with 10% APS yielded a softer texture. The RVA analysis of instant noodle formula dry mix showed that at the 10% APS level, all PS significantly increased noodle flour PV and FV. The RVA analysis of finished instant noodle powder indicated that at the 10% APS level, both PV and FV were significantly increased with 0.30% DSP or DKP, and 0.03% MSP was able to increase PV significantly. It was suggested that APS used in Korean non-fried instant noodle could be partially substituted by PS with minimal impact on finished product quality.

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1. Introduction

Asian noodles are an important part of the diet for the Asian population. About 20–50% of total wheat is used to produce noodles in Asia (Fu, 2008; Hou, 2001, 2010a). The instant noodle is the fastest expanding sector of all Asian noodles; it is gaining more popularity throughout the world (Hou, 2010a). Fried instant noodle has a distinctive flavor and texture due to the deep-frying process (Cheung et al., 2008; Park and Baik, 2004), but it has an average oil content of 15–22%. As consumers worldwide are increasingly concerned about health issues, the demand for a low fat, non-fried instant noodle has increased rapidly. The non-fried instant noodle is produced through similar procedures as the fried instant noodle except that, after steaming, it is dried by hot-air in a continuous chamber instead of being deep-fried in vegetable oil. Compared to the regular dried noodle (straight-cut noodle), the non-fried instant noodle is dried for a much shorter period of time at higher temperature and lower relative humidity (Hou et al., 2010).

The basic ingredients of Korean instant noodles are flour, water, salt, alkaline salts (sodium carbonate and potassium carbonate), and modified potato starch (Hou, 2010b). Every ingredient is important for producing high quality noodles. The overall ranking of noodle quality based on color and texture is largely independent of flour refinement (Kruger et al., 1994); however, the flour protein content plays an important role in determining the color and texture of the noodle (Baik et al., 1995). It has been reported that the noodle color and texture are also significantly affected by salt and alkaline salts (Miskelly, 1996). Salt tends to slow down the oxidative discoloration process under high temperature and high humidity environments (Fu, 2008), and to produce a noodle with softer and more elastic texture. Alkaline salts make the noodle yellower in color by reacting with flour flavones and yield more elastic texture by affecting the behavior of the gluten proteins (Fu, 2008; Hou and Kruk, 1998; Sawatari et al., 2005).

Starches and their derivatives have been added into the instant noodle formula to improve its processing (steaming) and end-use quality such as color and texture (Choy et al., 2011; Huang and Lai, 2010); for instance, in Korean instant noodle, up to 15% (total flour-starch blend weight) of modified potato starch is often used which leads to higher material cost. It would be of economic benefit to replace

Keywords:
Non-fried instant noodle
Phosphate salt
Acetylated potato starch
Rapid visco analyzer
Texture profile analysis

Abbreviation: ANOVA, analysis of variance; APS, acetylated potato starch; DKP, dipotassium phosphate anhydrous; DSP, disodium phosphate anhydrous; FV, rapid visco analyzer final viscosity; MSP, monosodium phosphate anhydrous; PS, phosphate salt; PV, rapid visco analyzer peak viscosity; RVA, rapid visco analyzer; TPA, texture profile analysis.

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if an alternative could be found to replace or partially replace modified potato starch in instant noodles without compromising the finished product quality.

Several researches have investigated the functionality of selected ingredients in instant noodle quality (Choy et al., 2011; Fitzgerald et al., 2003; Mouquet and Treche, 2001; Rai et al., 2008; Shih and Daigle, 1999; Yu and Ngadi, 2004), but no one else has reported the effects of phosphate salts (PS) on the quality characteristics of instant noodles. In one of our previous studies, we have discovered that some PS (or their blends) demonstrated the ability of modifying instant noodle dough pasting properties as determined by the Rapid Visco Analyzer (RVA) (Zhou and Hou, 2011). For the alkaline noodle, it was reported that the peak viscosity (PV) of noodle flour correlated positively with the sensory smoothness and negatively with the sensory hardness scores (Baik et al., 2003; Baik and Lee, 2003; Batey et al., 1997; Crosbie, 1991; Miskelly and Moss, 1985; Moss, 1980; Seib, 2000). In another study, we sampled 25 commercial instant noodle brands from 10 countries and conducted a descriptive sensory evaluation. We learned that the noodles containing modified starch gave a much springier, smoother, more elastic, and chewier texture than those without this ingredient (Wang et al., 2011). We further discovered in that study that 33% of total APS used in the Korean fried instant noodle could be substituted by 0.30% or less of the selected PS based on the noodle powder pasting properties and sensory evaluation results. It would be of interest to know whether these PS could have a similar impact on the Korean non-fried instant noodle because they are processed under different conditions. The objective of this research was to investigate the effects of selected PS on the quality of Korean non-fried instant noodle, including color, texture profiles and pasting properties.

2. Materials and methods

2.1. Materials

Hard white wheat flour was milled at the Wheat Marketing Center (Portland, Oregon, USA) on a pilot-scale, Miag-Multomat mill (Buhler-Miag Co., Switzerland), and its moisture, protein, and ash contents were 12.6%, 10.0% (14% moisture basis), and 0.40% (14% moisture basis), respectively. Three phosphate salts, monosodium phosphate (MSP), disodium phosphate (DSP), and dipotassium phosphate (DKP), were supplied by ICL Performance Products LP (St. Louis, MO, USA), Perfectamyl®AC, an acetylated potato starch (APS) was kindly provided by National Starch Food Innovation (New Jersey, USA), and had a moisture content of 14.9%. This APS product was developed to improve instant noodle texture by the manufacturer. All other chemicals were purchased from VWR (West Chester, PA, USA) and were of analytical grade.

2.2. Preparation of the Korean non-fried instant noodle

Based on our previous results of the Korean fried instant noodle (Wang et al., 2011), MSP, DSP, and DKP were selected to partially substitute APS in the Korean non-fried instant noodle at their optimal levels. The noodle dough formulas are listed in Table 1, including 85-15’ (regular Korean non-fried instant noodle formula containing 15% APS of total flour-APS blend weight), 90-10’ (modified Korean non-fried instant noodle formula containing 10% APS of total flour-APS blend weight), ‘DSP’ (90-10’ with additional 0.30% DSP), ‘DKP’ (90-10’ with additional 0.30% DKP), and ‘MSP’ (90-10’ with additional 0.03% MSP). First, sodium chloride, alkaline salts (sodium carbonate and potassium carbonate), and PS were pre-dissolved in water. Wheat flour and APS were weighed, thoroughly mixed in a plastic bag, and placed into a pilot-scale FR-E700 noodle dough mixer (Tokyo Menki Co., Ltd, Tokyo, Japan) and the correct amount of salt/alkaline salts/PS solution was added. The non-fried instant noodles were prepared through mixing and sheeting by a pilot-scale noodle line according to the procedure described by Hou (2010b). Briefly, the noodle formula dry mix and salt/alkaline salt solution were mixed for 5 min at 110 rpm, followed by mixing for 14 min at 60 rpm. The final thickness of the noodle dough sheet was 1.25 ± 0.03 mm after sheeting through six pairs of rollers on the pilot-scale noodle machine (WR8-100, Tokyo Menki Co., Ltd, Tokyo, Japan). Then, the noodle sheet was slit into 1.2 mm × 1.7 mm (thickness × width) strands with a #18 square type slitter and waved. After being steamed for 5 min at 100 °C in a tunnel steamer (Model LB-20, Electro-Steam Generator Corp., Alexandria, VA, USA), the noodle strands were cut and folded once to form blocks (125 ± 5 g). Finally, the noodle blocks were dried in an ESPEC Platinous Chamber (ESX-2CX, ESPEC North America, INC., Hudsonville, Michigan, USA) for 45 min at 90 °C with a relative humidity of 20% (noodle blocks were flipped over after 30 min to ensure more even drying). Hot-air dried noodles were cooled for 1 h at room temperature before packing into a sealed bag. Noodle production was conducted on two different days to generate duplicate samples for each group. The final noodle product was ground to pass through an 18-mesh sieve by a falling number grinder (Laboratory mill 3100, Pertin Instruments Inc., Springfield, IL, USA), and the noodle powder was used for color and RVA measurements.

2.3. pH measurement of the Korean non-fried instant noodle dough

The pH of Korean non-fried instant noodle dough was measured according to the AACC International Method 02–52.01 with slight modifications. 15 g of freshly prepared noodle dough (Table 1) were placed into a 250 mL beaker with 100 mL of deionized water. The mixture was agitated until the dough was fully suspended and free of lumps. After being stirred for 15 min by a magnetic stirrer, the suspension was allowed to stand and settle for 30 min. The supernatant was decanted into a 100 mL beaker and pH was measured with a pH meter (SevenEasy pH, Mettler-Toledo AG, Switzerland).

2.4. Color measurement of the Korean non-fried instant noodle

The color of instant noodle powder was measured with a Chroma Meter (CR-410, Camera Co., LTD, Osaka, Japan). It was reported as L*, a* and b* values, which represents white-black, red-green and yellow-blue, respectively. The total number of

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### Table 1

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Group</th>
<th>85-15</th>
<th>90-10</th>
<th>DSP</th>
<th>DKP</th>
<th>MSP</th>
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<tr>
<td>Flour</td>
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<td>850</td>
<td>900</td>
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<td>Acetylated potato starch</td>
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<td>100</td>
<td>100</td>
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<td>340</td>
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<td>340</td>
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<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Alkaline salt&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
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<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Phosphate salt</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> The salt, alkaline salt, and phosphate salt were pre-dissolved in water.
<sup>b</sup> Alkaline salt comprised 80% potassium carbonate and 20% sodium carbonate.
measurements for each noodle group was 12 times and the average and standard deviation (SD) were reported.

2.5. Measurement of the RVA pasting properties of the Korean non-fried instant noodle formula dry mix and instant noodle product

The pasting properties of the Korean non-fried instant noodle formula dry mix were determined according to the previously described procedure (Wang et al., 2011) with the RVA-4 series (Perten Instruments Inc., Springfi eld, IL, USA). Briefly, 3.5 g noodle formula dry mix and 25 mL of water were mixed to form a slurry. Ingredients in each dry mix were measured according to the formula listed in Table 1. For example, the ‘85–15’ group contained: flour (2.930 g), APS (0.517 g), sodium chloride (0.0517 g), potassium carbonate (0.003 g), and sodium carbonate (0.0007 g). The slurry was stirred by the analyzer at 960 rpm for 10 s, and then at 160 rpm for the remainder of the test. During the RVA test, the slurry was held at 60 °C for 2 min, heated to 95 °C at 5.83 °C/min over 6 min, held at 95 °C for 4 min, cooled to 50 °C at 11.2 °C/min over 4 min, and held at 50 °C for 4 min. The RVA results were expressed in rapid visco units (RVU). The modiﬁed formula dry mix of non-fried instant noodle dough (‘90–10’, 90:10 flour to APS ratio) was: flour (3.078 g), APS (0.342 g), sodium chloride (0.0517 g), potassium carbonate (0.003 g), and sodium carbonate (0.0007 g). The ‘DSP’, ‘DKP’, and ‘MSP’ were the modiﬁed formulas of ‘90–10’ with additional 0.010 g DSP, 0.010 g DKP, and 0.001 g MSP, respectively.

The pasting parameters of the ground instant noodle powder were determined similarly.

2.6. Textural profile analysis of the Korean non-fried instant noodle

Cooked noodle textural properties were determined by using a TA-XT Plus Texture Analyzer (Texture Technology Corp., NY, USA) according to the methods described by Hou (2010b). Briefly, one noodle block was cooked in boiling water for 5 min, and rinsed in 26–27 °C water for 10 s with stirring. Non-fried instant noodle is not involved in deep-frying, so it has a much denser structure than the fried instant noodle; as a result, a longer cooking time was used to ensure the noodle was fully cooked for textural measurement.

After being placed in a plastic strainer, the excess water was drained by tapping the strainer forcefully 10 times (about 10 s) on the edge of a sink. Finally, the noodle was put in a covered bowl for texture profile analysis (TPA). To ensure sample consistency, one noodle block was cooked and analyzed at a time. TA-XT Plus settings for the TPA are: Load cell: 5 kg; Mode: TPA; Pre-test speed: 4 mm/s; Test speed: 1 mm/s; Post-test speed: 1 mm/s; Strain: 70%; Time: 1 s; Trigger type: Auto – 10 g; Acquisition: 200 pps; Probe: TA-47 W Pasta Blade (5-mm thickness ﬂat blade). Four textural parameters were recorded, and they were hardness, springiness, cohesiveness, and resilience. The measurements were repeated 2 or 3 times for each cooked noodle sample until the coefﬁcient of variation (C.V.) % of cooked noodle hardness was less than 5%. Because the noodle making was duplicated and two noodle blocks from each group were cooked for textural measurement, there were at least 8 readings of each parameter for each treatment group. The averages and standard deviations (SD) were reported.

2.7. Statistical analysis

All tests were run at least in triplicate unless speciﬁed, in a completely randomized design. Results are expressed as mean ± SD. Data were analyzed by one-way analysis of variance (ANOVA) with Student–Newman-Keuls post hoc test. Statistical signiﬁcance was set at the 5% signiﬁcance level.

3. Results and discussion

3.1. Effect of PS on the Korean non-fried instant noodle color

Color is an important quality criterion for noodles because consumer’s fi rst opinion of noodle is usually based on a visual assessment of appearance. For instant noodles, a bright and light yellow color is desirable by most consumers (Park and Baik, 2004). The color measurement results of instant noodle powder are shown in Table 2. It was shown that the noodle color became signiﬁcantly darker and more yellow by decreasing the APS content from 15% to 10%. This observation agrees with the common practice in Asia to use potato starch, tapioca starch or modiﬁed starches to brighten noodles (Ozturk et al., 2009). The L* values of all PS noodle groups were signiﬁcantly higher than that of the ‘90-10’ group. Instant noodles of the ‘DSP’ and ‘DKP’ groups had even higher L* values than the ‘85–15’ group. The b* values of all PSs groups were signiﬁcantly higher (P < 0.05) than that of the ‘85–15’ group, while the b* value of the ‘DSP’ group was signiﬁcantly higher than that of the ‘90-10’ group. The a* values of all the PS groups were lower (P < 0.05) than those of the ‘85–15’ and ‘90-10’ groups. These results indicated that the instant noodle color was brighter, yellower and greener with the addition of PS.

The darkening of noodles is generally attributed to the presence of phenolic substrate oxidizing enzymes such as polyphenol oxidases (PPO) (Morris et al., 2000), and the involvement of non-PPO darkening mechanisms (Fuerst et al., 2010). Some studies have shown the optimum pH range for most plant PPOs is from 4.5 to 8.0 (Duanngal and Apenten, 1999; Kavrayan and Aydemir, 2001). For example, the optimum pH for PPO activity in the freshly-cut potato was 7.6, above which its activity was substantially reduced as pH increased (Liu et al., 2009; Lu et al., 2006). Kinetic studies of wheat PPO by Anderson and Morris (2001) indicated that, at pH 6.5, two substrates (L-DOPA and catechol) produced the greatest enzyme activity with little auto-oxidation, although the dihydroxyphenolic substrates exhibited increased auto-oxidation levels at pH 8.5. The noodle dough pH values of the ‘DSP’, ‘DKP’, and ‘MSP’ groups were 9.27, 9.37, and 9.36, respectively, slightly higher than that of the ‘90-10’ group (pH 9.20), which could slightly inhibit PPO activity during noodle dough mixing and sheeting processes. For the non-enzymatic darkening, some have suggested that metallic cations may catalyze the reaction (Theuer, 2002). Since the PS has a metal-chelating effect, it may have the function of inhibiting non-enzymatic darkening of noodles. After steaming and hot-air drying, the PPO was deactivated and therefore, would not cause further discoloration in the ﬁnished product.

Alkaline noodles owe their characteristic yellow color to the chromophoric shift that occurs when endogenous flavonoids found

<table>
<thead>
<tr>
<th>Sample</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>85-15</td>
<td>88.87 ± 0.007&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.47 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.90 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>90-10</td>
<td>87.40 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.49 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.76 ± 0.22&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DSP</td>
<td>89.14 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.67 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.21 ± 0.45&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DKP</td>
<td>89.08 ± 0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.72 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.88 ± 0.17&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>MSP</td>
<td>88.94 ± 0.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.54 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.96 ± 0.11&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD (n = 12). Values in the same column with different superscript letters are signiﬁcantly different (P < 0.05).

L*, lightness; a*, redness-greenness; b*, yellowness-blueness.

<sup>a</sup>85–15, regular formula of Korean non-fried instant noodle powder containing 15% APS of total ﬂour-APS blend weight; 90-10, modiﬁed formula of Korean non-fried instant noodle powder containing 10% APS of total ﬂour-APS blend weight; ‘DSP’, modiﬁed formula ‘90-10’ with additional 0.30% DSP; ‘DKP’, modiﬁed formula ‘90-10’ with additional 0.30% DKP; ‘MSP’, modiﬁed formula ‘90-10’ with additional 0.03% MSP.
in the flour react in the presence of caustic solutions of kansui (sodium and potassium carbonates) (Bellido and Hatcher, 2009; Hatcher and Anderson, 2007; Sawatari et al., 2005). The intensity of the yellowness is a function of the alkali used (Miskelly, 1996) and the amount of flavonoids present. Because the addition of PS increased the noodle dough pH, it would be expected to cause yellower noodle color.

### 3.2. Effect of PS on the cooked noodle texture

Texture of cooked noodles is one of the major quality attributes that determine noodle eating quality. There have been many attempts to develop reproducible and reliable instrumental methods to determine noodle texture and the role of flour components and ingredients/additives on the textural properties of cooked noodles (Baik, 2010; Hatcher, 2010; Ross, 2006; Ross and Crosbie, 2010). However, each method has its limitation that it does not truly measure sensory attributes (Ross, 2006; Ross and Crosbie, 2010). Textural profile analysis (TPA) has been proposed by many researchers and is one of the most widely accepted instrumental methods to estimate the sensory texture attributes of cooked noodles (Baik, 2010; Hatcher, 2010; Ross, 2006).

Starch, especially modified starch, is widely used in various Asian noodles to modify their texture (Choy et al., 2011). Acetylated starches have shown many positive characteristics such as low gelatinization temperature, high swelling power and viscosity, increased solubility, and good stability under freeze-thaw conditions (Jae et al., 1993; Liu et al., 1999). When up to 20% of wheat flour was replaced by acetylated potato or sweet potato starches in a white salted noodle, the cooking loss was significantly decreased and the cooked noodle softness, stretchability and slipperiness were significantly increased (Chen et al., 2003). Previous studies from our own lab showed that in the fried instant noodle, the addition of APS made the noodle softer, springier and shinier (Wang et al., 2011). Some researchers also found that the use of modified starch improved noodle texture by making noodle more elastic and chewy (Fang, 1999; Sandhu et al., 2010). Other benefits of using APS in instant noodle include shortening the rehydration time (Fu, 2008) and better appearance of cooked noodle (smoother and shinier surface).

The textural properties of the cooked noodles are summarized in Table 3. It was noticed that there were slight differences in springiness, cohesiveness, and resilience among the five groups. The springiness, resilience and cohesiveness of the ‘85-15’ group were slightly higher than those of the other four groups. It was speculated that, as the APS content was reduced from 15% to 10%, there were fewer starch molecules to establish junction zones of adequate size to form an elastic network (Yadav et al., 2007).

### 3.3. Effect of PS on the pasting properties of Korean non-fried instant noodle formula dry mix

Several studies have reported that starch pasting properties of noodle flour, including high peak viscosity, high breakdown and swelling power are responsible for superior noodle quality of Japanese and Korean type noodles (An and King, 2009; Crosbie, 1991; Crosbie et al., 1992, 1998; Crosbie and Ross, 2004; Konik et al., 1992; Moss, 1980; Noitang et al., 2009; Singh et al., 2009). The pasting parameters of Korean non-fried instant noodle formula dry mixes are shown in Table 4.

For the ‘85-15’ group, the peak viscosity (PV) was significantly higher than that of the group ‘90-10’, while the pasting temperature was significantly lower. These results confirmed that the amount of APS in the noodle formula had a significant impact on noodle flour pasting properties and gelatinization temperature. It has been reported that acetylation of starch increases swelling power and viscosity but decreases gelatinization temperature (Fu et al., 2008; Kim et al., 1996; Liu et al., 1999; Wang et al., 2011). The PV values of the ‘DSP’, ‘DKP’, and ‘MSP’ groups were significantly higher than that of the ‘90-10’ group, which were confirmed by our earlier findings that PS was very effective in improving noodle flour PV value (Wang et al., 2011; Zhou and Hou, 2011). PS did not show any effect on noodle flour pasting temperature.

During the RVA test, the viscosity of noodle formula dry mix first increased due to the swelling of starch granules. After the gelatinized starch reached its peak viscosity, under continuous shearing at 95 °C, the greatly swollen starch granules began to disintegrate due to crowding and mutual pressure, resulting in dramatic decrease in viscosity (Collado and Corke, 1999). The rate and extent of reduction from PV depend on the temperature, the degree of mixing or shear stress applied to the mixture, and the nature of the material. The cross-linked starch was reported having the ability of resistance to such breakdown (Fu, 2008; Sajiñala and Singhal, 2005; Tan et al., 2009). The trough value was significantly higher in the ‘DSP’, ‘DKP’ or ‘MSP’ groups compared to that of the ‘90-10’ and ‘85-15’ group (Table 4). It was hypothesized that the short-chain starch molecules cross-linked with PS and they formed a highly ordered crystalline structure (Wang et al., 2011). This explanation was confirmed by an earlier report (Wang et al., 2000).

### Table 3

<table>
<thead>
<tr>
<th>Hardness (g)</th>
<th>Springiness</th>
<th>Cohesiveness</th>
<th>Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>85-15</td>
<td>1179.86 ± 23.34</td>
<td>0.964 ± 0.0014&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.645 ± 0.0057&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>90-10</td>
<td>1309.23 ± 18.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.961 ± 0.0075&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.615 ± 0.011&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DSP</td>
<td>1285.77 ± 25.58&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.963 ± 0.011&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.632 ± 0.015&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DKP</td>
<td>1224.50 ± 43.55&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.962 ± 0.015&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.636 ± 0.014&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>MSP</td>
<td>1297.74 ± 37.83&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.957 ± 0.016&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.632 ± 0.012&lt;sup&gt;b&lt;/sup&gt;</td>
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</tbody>
</table>

Data are expressed as means ± SD (n = 8). Values in the same column with different superscript letters are significantly different (P < 0.05).<sup>±</sup> Means values in the same column are not significantly different.

‘85-15’, regular formula of Korean non-fried instant noodle powder containing 15% APS of total flour-APS blend weight; ‘90-10’, modified formula of Korean non-fried instant noodle powder containing 10% APS of total flour-APS blend weight; ‘DSP’, modified formula ‘90-10’ with additional 0.10% DSP; ‘DKP’, modified formula ‘90-10’ with additional 0.30% DKP; ‘MSP’, modified formula ‘90-10’ with additional 0.03% MSP.
The holding period of the test at 95°C is commonly associated with breakdown of starch viscosity. The breakdown value is the difference between the peak viscosity and trough and is considered as a measurement of the degree of starch disintegration or paste stability (Dufour et al., 2009). During breakdown period, the swollen granules disrupt further, and amylose molecules leach out into the solution (Zhang et al., 2008). The breakdown value of the ‘90-10’ group was significantly lower than that of the ‘85-15’ group, which was ascribed to the reduced content of APS from 15% to 10%.

A number of previous researches have reported that the larger structure and, therefore, cause the FV to increase. Ragaee and Aal (2005; Noda et al., 2006; Noitang et al., 2009; Sandhu et al., 2010) showed slightly lower setback value than the ‘90-10’ group, suggesting that PS had little impact on amylose retrogradation of noodle flour.

### Table 4

<table>
<thead>
<tr>
<th>Sample</th>
<th>Peak viscosity</th>
<th>Trough</th>
<th>Breakdown</th>
<th>Final viscosity</th>
<th>Setback</th>
<th>Pasting temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85-15</td>
<td>308.96 ± 1.47e</td>
<td>154.54 ± 0.65b</td>
<td>154.42 ± 2.12c</td>
<td>303.17 ± 3.18a</td>
<td>148.63 ± 2.54c</td>
<td>65.60 ± 0.21f</td>
</tr>
<tr>
<td>90-10</td>
<td>268.71 ± 0.30a</td>
<td>135.05 ± 2.65a</td>
<td>133.67 ± 2.95c</td>
<td>276.50 ± 1.77b</td>
<td>141.46 ± 0.88a</td>
<td>66.60 ± 0.10b</td>
</tr>
<tr>
<td>DSP</td>
<td>298.00 ± 0.11a</td>
<td>178.75 ± 4.13c</td>
<td>119.25 ± 4.24c</td>
<td>319.54 ± 3.48b</td>
<td>140.79 ± 0.65c</td>
<td>66.46 ± 0.23b</td>
</tr>
<tr>
<td>DKP</td>
<td>285.13 ± 1.35b</td>
<td>174.21 ± 3.01h</td>
<td>110.92 ± 1.65c</td>
<td>311.50 ± 4.84b</td>
<td>137.29 ± 1.82c</td>
<td>66.61 ± 0.34b</td>
</tr>
<tr>
<td>MSP</td>
<td>299.29 ± 0.76a</td>
<td>184.17 ± 2.00d</td>
<td>115.13 ± 1.24c</td>
<td>323.67 ± 1.18c</td>
<td>139.50 ± 0.82c</td>
<td>66.07 ± 0.52c</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD (n = 3). Values in the same column with different superscript letters are significantly different (P < 0.05).

The pasting parameters of the ground non-fried instant noodle powder are shown in Table 5. Since the instant noodles had been steamed for 5 min at 99–100°C and hot-air dried for 45 min, the remaining ungelatinized starch was largely responsible for the pasting properties, which is a reflection of the degree of steaming and starch retrogradation of the finished product. This degree of steaming (cooking) and starch retrogradation (after cooling and during storage) may also have an impact on instant noodle rehydration and eating quality when prepared for consumption.

Similar to the pasting properties of instant noodle formula dry mix (Table 4), the PV and FV values of the ‘85-15’ group instant noodle powder were significantly higher than those of the ‘90-10’ group (Table 5). Similarly, the PV values of the ‘DSP’, ‘DKP’, and ‘MSP’ noodle groups were significantly higher than that of the ‘90-10’ noodle group. The noticeable examples were the ‘DSP’ and ‘DKP’ noodle groups, whose PV values were even significantly higher than that of the ‘85-15’ group. The trough values were higher in ‘DSP’ and ‘DKP’ noodle groups as compared to the ‘90-10’ group.

The breakdown value of the ‘90-10’ noodle group was significantly lower than that of the ‘85-15’ group due to reduced content of APS from 15% to 10%. However, all three PS groups had significantly higher breakdown values than the ‘90-10’ group which was in contrast to the results of the instant noodle formula dry mix. The reason could be that the remaining ungelatinized starch and retrograded starch in the PS noodle products was less heat stable and tended to breakdown more easily during the RVA test.

### Table 5

<table>
<thead>
<tr>
<th>Sample</th>
<th>Peak viscosity</th>
<th>Trough</th>
<th>Breakdown</th>
<th>Final viscosity</th>
<th>Setback</th>
<th>Pasting temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85-15</td>
<td>182.10 ± 1.44e</td>
<td>174.17 ± 3.62h</td>
<td>7.93 ± 1.89a</td>
<td>369.13 ± 7.34e</td>
<td>194.96 ± 4.18c</td>
<td>85.38 ± 0.43f</td>
</tr>
<tr>
<td>0-10</td>
<td>150.73 ± 3.33a</td>
<td>152.20 ± 4.66d</td>
<td>-2.88 ± 3.65d</td>
<td>327.60 ± 7.17e</td>
<td>175.40 ± 2.86f</td>
<td>86.18 ± 0.67</td>
</tr>
<tr>
<td>DSP</td>
<td>190.98 ± 6.61d</td>
<td>166.84 ± 5.74e</td>
<td>24.14 ± 3.47b</td>
<td>348.08 ± 11.48c</td>
<td>181.24 ± 6.16b</td>
<td>85.71 ± 0.62</td>
</tr>
<tr>
<td>DKP</td>
<td>191.32 ± 5.80e</td>
<td>167.62 ± 4.98b</td>
<td>23.70 ± 7.73c</td>
<td>348.26 ± 7.45d</td>
<td>180.65 ± 3.51c</td>
<td>85.78 ± 0.51</td>
</tr>
<tr>
<td>MSP</td>
<td>167.37 ± 4.14b</td>
<td>154.49 ± 3.71d</td>
<td>12.89 ± 1.38c</td>
<td>333.40 ± 6.08c</td>
<td>178.92 ± 2.63e</td>
<td>86.31 ± 0.23</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD (n = 6). Values in the same column with different superscript letters are significantly different (P < 0.05). Values in the same column with different superscript letters are significantly different (P < 0.05).
‘MSP’ noodle groups were higher than that of the ‘90-10’ group, suggesting that higher amylose retrogradation occurred in the PS noodle products. It has been reported that the retrogradation of starch, associated with the syneresis of water and crystallization of amylopectin, led to harder gels (Goesaert et al., 2008; Singh et al., 2010).

It was noticed that there was no significant difference in pasting temperature among all noodle products. The reason was perhaps that the instant noodle pasting properties had been altered after being steamed and dried, which concurred with the previous findings (Bui and Small, 2007; Ragae and Aal, 2006; Wang et al., 2011).

In the survey of 25 commercial instant noodle samples, we found that the four noodle brands that contained modified potato starch not only exhibited much higher RVA peak, trough, and final viscosities, but also springier, smoother, and more elastic texture by descriptive sensory evaluation (Wang et al., 2011). The results showed that the RVA profile of instant noodle powder could be a useful noodle texture indicator. The study further confirmed that, in the fried instant noodle, when 30% APS was replaced by small amount of selected PS, the RVA parameters were maintained or slightly improved. Finished noodles also had similar sensory textural characteristics to the original control noodle. It is therefore speculated that improving or at least maintaining the RVA parameters of non-fried instant noodles, when APS is partially substituted with PS, could have a similar impact on the noodle eating properties.

In this study, the PV values of ‘DSP’ and ‘DKP’ noodle groups were significantly higher than those of the ‘90-10’ and ‘85-15’ groups, while trough and PV values were slightly lower than those of the ‘85-15’ group, suggesting that both ‘DSP’ and ‘DKP’ noodle groups could have very similar sensory texture to the regular formula noodle group ‘85-15’. These further imply that either DSP or DKP or their blend could be used in the Korean non-fried instant noodles to partially substitute the APS in the formulation without imposing any significant impact on the noodle sensory texture characteristics. The ‘MSP’ noodle group had a significantly higher PV value than that of the ‘90-10’ group, while both trough and final viscosities were similar, which indicates that 0.03% MSP may only have a slight improvement on the noodle sensory texture characteristics.

4. Conclusion
The Korean non-fried instant noodle displayed a brighter and yellower appearance with the addition of three PS (MSP, DSP, and DKP). Meanwhile, similar to the effect of APS, all PS made the cooked noodle softer in texture as confirmed by the result that PS significantly increased noodle flour PV and FV values. As for the non-fried instant noodle pasting properties, all three PS increased the PV, trough, and FV values. The use of 0.30% DSP or DKP showed a greater impact on increasing the PV value of instant noodle than 5% APS. The results suggested that the APS used in the Korean non-fried instant noodle could be partially substituted by small amounts of selected PS or their blends.

Conflict of interest
The authors state that they have no conflict of interest.

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