**Note**

Rheological, Thermal and Textural Properties of Starch Blends Prepared from Wheat and Turkish Bean Starches

Shahzad HUSSAIN*, Mohammed S. ALAMRI and Abdellatif A. MOHAMED

Department of Food Science & Nutrition, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

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Wheat starch (WS) and Turkish bean starch (TBS) blends were prepared in different proportions like 100WS, 10TBS/90WS, 30TBS/70WS, 50TBS/50WS and 100TBS. Starch blends and individual starches were studied for their pasting, thermal, textural and functional properties. Differential scanning calorimetry (DSC) thermograms of blends showed additive effect of both the starches. Gelatinization enthalpy of individual TBS was higher as compared to individual WS. In 50TBS/50WS blend, effect of TBS was higher as compared to WS. Amylose lipid complex was observed in individual WS and all blends while it was not present in individual TBS. Syneresis from starch gels increased with the increase in TBS level in blends. All the blends showed a linear trend regarding gel hardness values. The cohesiveness value of 50WS/50TBS blend was almost similar to that of 100WS. Our studies suggest that blending of WS with TBS in equal proportions can be useful in high temperature processing.

Keywords: turkish bean starch, wheat starch, blends, DSC, RVA, texture

*To whom correspondence should be addressed. E-mail: shhussain@ksu.edu.sa

**Introduction**

Starch is considered to be a main component in a balanced human diet. The properties of starches obtained from different botanical sources vary due to difference in their amylose content, grain size and chain length distribution of amylpectin branches (Ellis et al., 1998). Every starch has different functional properties but generally they are used as gelling and thickening agents in foods and to modify the textural properties. The native starches are sometime difficult to use in some food application because of their inherited deficiencies like thermal decomposition, limited shear stress resistance, more retrogradation and syneresis (Sivoli-Rodriguez and Pérez-Sira, 1996). Starches are modified to attain the desirable properties. Physical, chemical and enzymatic modifications are the commonly used methods for starch modification. Hydrocolloids gums are also used to modify the functional properties of native starches (Alamri et al., 2012; Alamri et al., 2013; Nagano et al., 2008). The modification of starches can result in an increase in the starch price by many times (Bello-Pérez et al., 2001). Due to market demand for natural food ingredients, it is therefore necessary to find alternative ways of starch modifications instead of commonly used methods. The use of starch blends from different natural starch sources is an economical approach to get the desired properties for various food applications (Novelo-Cen and Betancur-Ancona, 2005). Several researchers have studied many starch blends systems and reported that blending in various proportions of different starches promotes desirable pasting and gelling properties (Zhu and Cork, 2011; Laura et al., 2006; Novelo-Cen and Betancur-Ancona, 2005; Sandhu et al., 2010). The properties of different blended starches can be studied by various methods like Rapid visco analyzer, differential scanning calorimeter, syneresis studies, gel texture and image analysis (Laura et al., 2005; Sandhu et al., 2010; Hangenimana et al., 2005; Gunaratne and Corke, 2007). Although, a number of studies are carried out to study many types of starch blends, but to best of our knowledge no studies are done to investigate the blending of wheat starch with Turkish bean starch. The main objectives of our research work were to study the gelatinization behaviors of blends prepared from wheat and Turkish bean starches using rapid visco analysis, differential scanning calorimeter and light microscopy. Furthermore syneresis and texture studies on
blended starch gels were also carried out.

### Material and Methods

#### Materials
Hard red spring wheat flour and Turkish white dry beans (TB) (*Phaseolus vulgaris* var. pinto) were obtained from local market.

#### Methods

**Starch Isolation from Turkish beans and wheat** Slurry was prepared by mixing Turkish bean (TB) meal in distilled water (50/50) in heavy duty blender for 5 min. The slurry was filtered through 200 mesh sieve. The filtrate was then centrifuged at 2000 × *g* for 15 min. After centrifugation, the supernatant was removed and the white pellet at the bottom of the bottle was re-suspended in distilled water and centrifuged at the same conditions mentioned above. This process was repeated 5 times after which a white pure starch fraction was obtained. Martin process (Knight and Olson, 1984) was used for the isolation of wheat starch. Dough was prepared by adding water in flour (flour/ water ratio 2:1, w/w). Dough ball was washed with excess amount of water by kneading on cheese cloth. Washing was performed till milkyness of the filtrate coming from the cloth sieve was disappeared. The filtrate was then centrifuged at 2000 × *g* for 20 min. After centrifugation, waxy layer on top was removed and the white material at the bottom of the bottle was dispersed with distilled water and centrifuged till pure white starch fraction was obtained. The starch from both sources was dried using acetone and ground in coffee grinder. The starch powders were then transferred to air tight glass bottles and stored at 4°C till further use.

**Starch blends** Different blends of wheat starch (WS) and Turkish bean starch (TBS) were prepared in following four proportions; 100WS, 10TBS/90WS, 30TBS/70WS, 50TBS/50WS while 100% TBS was also used for comparison. All the blends were stored in air tight containers at 4°C till further used for different experiments.

**Differential Scanning Calorimetry (DSC)** DSC analysis was conducted to determine the thermal properties of starch blends using Setaram instruments Mico DSC III Evo. Sample (240 mg) was placed in Standard Hastelloy cell and 400 µL distilled water was added, while the reference cell contained suitable amount of distilled water. After sealing, the sample was equilibrated for 1 h and then scanned from 20 to 110°C at a heating rate of 2°C/min. Gelatinization parameters, (∆*H* J/g), onset temperature, and peak temperature were determined using DSC Calisto Processing software. In addition, the same parameters were calculated for the amyllose lipid complex observed in the same scan.

**Rapid Visco analyzer measurements (RVA)** Pasting properties of the starch blends were determined using a Rapid Visco Analyzer (Newport Scientific, Sydney, Australia). Starch blends (3 g at 14% moisture basis) were directly weighed into aluminum RVA canisters and distilled water was added to achieve a total weight of 28 g. The obtained slurry was held at 50°C for 30 s, heated to 95°C in 4.40 min (at 10.23°C/min) and held at 95°C for 4 min. It was then cooled to 50°C in 2 min (at 22.5°C/min) and held at 50°C for 2 min. The rotating speed of paddle was 960 rpm for first 10 s and then reduced and kept at 160 rpm throughout the remainder experiment. All measurements were replicated twice and the Thermocline window software was used to process the data.

**Texture studies on starch gels** Gel texture parameters were determined on RVA-prepared gel. The gels (35 mm in height) were transferred to 25 mL beakers having internal diameters of 30 mm and stored overnight at room temperature. Gels were compressed using Brookfield CT3 Texture Analyzer (Brookfield Engineering Laboratories, Inc. Middleboro, USA) in two penetration cycles at a speed of 0.5 mm/s to a distance of 10 mm using 12.7 mm wide and 35 mm high cylindrical probe. Gel hardness, springiness, cohesiveness and adhesiveness were recorded. The gumminess was calculated as a product of hardness and cohesiveness while chewiness as a product of gumminess and springiness.

**Syneresis studies on starch gels** Gels obtained from RVA canisters were shifted to graduated centrifuge tubes and stored in the freezer at −20°C. Next day of storage, gels were placed in water bath at 50°C for 30 min and then centrifuged at 3000 × *g* for 15 min. The water separated from gels was recorded and the gels were restored in freezer and water separation after 30th and 60th days was recorded using same procedure. Percent syneresis recorded for the three freeze-thaw cycles was reported on 1st day, 30th day and 60th days of storage period. Following equation was used to calculate % syneresis.

\[
\% \text{syneresis} = \frac{A-B}{A} \times 100
\]

*A* = weight of gel before centrifugation

*B* = weight of gel after removing the water expelled during centrifugation

**Light microscopy of starch gels** Cooked starch gels of different blends were placed on glass slides and images of their microstructure were taken at 40 × magnification using a light microscope Model. 591300 Wolfe, Digivu, TM, CVM, Carolina Biological Supply Company, Burlington, North Carolina, USA.

**Statistical analysis** All measurements were done in triplicate. Data was subjected to one-way analysis of variance and Duncan’s Multiple Range (DMR) test at *p* ≤ 0.05 was used to compare means using PASW® Statistics 18 software.
Results and Discussion

Thermal properties  Results of the gelatinization temperature (onset and peak values) and enthalpies are presented in Table 1 while their corresponding thermo grams are shown in Fig. 1. Gelatinization enthalpy (ΔH) of individual TBS was higher (14.3 ± 0.08 J/g) than that of individual wheat starch (9.75 ± 0.75 J/g). Furthermore, wheat starch also showed a second endothermic peak at 100.07°C representing the melting of amylose-lipid complex. The melting temperature of amylose-lipid complex significantly shifted to lower temperatures with the increase in blending proportion of TBS in WS. However, no amylose-lipid complex melting transition was noticed in individual TBS. The gelatinization enthalpies of blends containing 10 and 30% TBS were more influenced by WS that can be attributed to more smaller size WS granules surrounding bigger size TBS granules which resulted in full gelatinization. The findings are also supported by the earlier studies of Sun and Yoo (2011), Ortega-Ojeda and Eliasoon (2001). At 50 − 50% TBS and WS blends, ΔH was significantly higher (11.85 ± 0.33 J/g) than other blends possibly due to the presence of more large size granules of TBS, as supported by the findings of Kaur et al. (2009). The transitions temperatures i.e onset temperature (OT) and peak temperature (PT) of the blends were closer to WS than those of TBS, suggesting that WS has more influence in blends as compared to TBS. The Peak temperature varied from 58.96 ± 0.02°C to 56.83 ± 0.32°C among the three starch blends. The PT of individual WS was 58.81 ± 0.10°C while TBS starch possessed 70.5 ± 0.42°C. Interestingly the PT of blends increased linearly in blends containing 10 and 30% TBS but it was significantly reduced to 56.83 ± 0.32°C in 50 − 50 WS and TBS blend. The 50 − 50 starch blend can be a suitable choice for baby foods and pie fillings because of having lower gelatinization temperature (Betancur-Ancona et al., 2001). The OT of 100% WS was 52.43 ± 0.05, which was increased to 52.77 ± 0.05°C in 10/90 blend and 52.68 ± 0.53°C in 30/70 blend and finally reduced to 48.98 ± 0.23 in 50/50 WS: TBS blend. The influence of WS in 10/90 and 30/70 blends was higher as the abundance of relatively smaller granular size WS surrounded the larger size TBS granules, which ultimately delayed the onset of gelatinization in 10/90 and 30/70 blends but at 50/50 level of blending, TBS having relatively larger size granules showed more effect which resulted in start of earlier gelatinization. The images shown in Fig. 4 (e, f, g) also explains how different levels of two starches affected the gelatinization behavior of different blends. This can be attributed to the difference in granule size of starches. Smaller grains generally gelatinize slowly and at higher temperatures. Similar results are also noticed in canna starch and mung bean starch blends by (Puncha-aron et al., 2008); they also reported that Potato, mung bean and rice starches having mean granule size of 48, 24 and 7 μm showed gelatinization temperature of 65.8, 70.1 and 75.2°C, respectively. It is clear from the Fig. 1 that all the starch blends and individual starches showed a single endothermic peak. The 100% TBS peak was broader with a slight shoulder as compared to 100% WS where the main peak was narrow but a second peak around 100°C represented the amylose lipid complex. Additive behavior in thermal transitions was observed in all starch blends at all levels due to competition for water. The appearance of single endothermic peak may be due to the reason that WS peak is merged with relatively broader peak of TBS. Similar results were also noticed in another study

![Fig. 1. DSC thermograms of different starch blends.](image-url)

<table>
<thead>
<tr>
<th>Blends</th>
<th>ΔH J/g</th>
<th>P T°C¹</th>
<th>O T°C²</th>
<th>ALC ΔH J/g</th>
<th>ALC P T°C³</th>
<th>ALC O T°C³</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 WS</td>
<td>9.75 ± 0.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58.81 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.43 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.27 ± 0.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100.22 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.37 ± 0.47&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>10TBS/90WS</td>
<td>10.12 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58.96 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.77 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.98 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100.09 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>93.74 ± 0.17&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>30TBS/70WS</td>
<td>9.98 ± 0.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>59.08 ± 0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>52.68 ± 0.53&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.71 ± 0.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>100.14 ± 0.20&lt;sup&gt;c&lt;/sup&gt;</td>
<td>94.83 ± 0.89&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>50TBS/50WS</td>
<td>11.85 ± 0.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56.83 ± 0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.98 ± 0.23&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.20 ± 0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>99.66 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95.21 ± 0.30&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>100 TBS</td>
<td>14.30 ± 0.08</td>
<td>70.5 ± 0.42</td>
<td>57.70 ± 1.80</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<sup>1</sup> Peak T°C,  <sup>2</sup> Onset T°C,  <sup>3</sup> Amylose lipid Complex ΔH (J/g),  <sup>4</sup> Amylose lipid Complex Peak T°C,  <sup>5</sup> Amylose lipid Complex Onset T°C.

Means carrying same letters in the columns are statistically non significant.
on canna and mung bean starch blends (Puncha-aron et al., 2008). The results of our study were also supported by earlier findings of Liu and Lelievre (1992) who reported a single endothermic transition in rice-potato starch blends.

**Pasting properties** The results of pasting properties of wheat and Turkish bean individual starches and their mixtures are presented in Table 2 and profiles are shown in Fig. 2. There was a significant difference among the peak viscosities, breakdown, peak temperatures and times of different WS and TBS blends while final viscosities and set back viscosities were non significantly different. As the level of TBS in WS was increased, Peak viscosity decreased. These results are expected because the Peak Viscosity of individual WS was higher (2168.33 ± 147 cP) as compared to individual TBS (1966.33 ± 49.94 cP). The blends containing 10% TBS was higher (2168.33 ± 147 cP) as compared to individual WS and TBS blends while final viscosities and set back viscosities were non significantly different. As the level of TBS in WS was increased, Peak viscosity decreased. These results are expected because the Peak Viscosity of individual WS was higher (2168.33 ± 147 cP) as compared to individual TBS (1966.33 ± 49.94 cP). The blends containing 10% TBS was statistically similar in peak viscosity with 100% WS while 30 and 50% TBS containing starch blends showed properties similar to TBS. The pasting temperature of TBS (75.82 ± 0.77°C) was lower as compared to individual WS (87.68 ± 0.63°C). Due to this reason, pasting temperature of starch blends decreased with the increase in level of TBS in starch blends. The decrease in pasting temperature of blends as the level of TBS was increased can be attributed to the granular size of starch. The TBS has relatively larger size starch granules as compared to WS. Though the final viscosity of TBS was higher (3003.33 ± 166.56 cP) than that of WS (2605.00 ± 97.25 cP), the variation in final viscosity of different blends was non significant. The higher levels of Final viscosity of starch blends represents that all the blends are stable during heating and cooling cycles can perform better during agitation and shear stress. Our blends can be used for baby foods because they can tolerate high temperature sterilization in contrast with some other commercial available starches which losses their consistency during processing (Villarcre and Espin, 1996; Novelco-cen and Betancur-Ancona, 2005).

**Gel textural properties** The textural properties of single and blended textural properties of individual WS and TBS and their blends were studied after storage for 24 h at 4°C using texture analyzer. The results pertaining to the various textural properties of individual WS and TBS and their blends are presented in Table 2 and profiles are shown in Fig. 2.

Table 2. RVA properties of starch blends.

<table>
<thead>
<tr>
<th>Blends</th>
<th>PV (cP)</th>
<th>Trough (cP)</th>
<th>Breakdown (cP)</th>
<th>Final Viscosity (cP)</th>
<th>Set back (cP)</th>
<th>Peak Time (min)</th>
<th>Peak Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 WS</td>
<td>2168.33 ± 147°</td>
<td>1287.33 ± 71.22°</td>
<td>881.00 ± 76.54°</td>
<td>2605.00 ± 97.25°</td>
<td>1317.67 ± 36.53°</td>
<td>6.53 ± 0.07°</td>
<td>87.68 ± 0.63°</td>
</tr>
<tr>
<td>10TBS/90WS</td>
<td>2178.67 ± 7.09°</td>
<td>1325.33 ± 25.70°</td>
<td>853.33 ± 18.61°</td>
<td>2579.00 ± 81.06°</td>
<td>1253.67 ± 106.76°</td>
<td>6.64 ± 0.10°</td>
<td>87.27 ± 0.33°</td>
</tr>
<tr>
<td>30TBS/70WS</td>
<td>1951.00 ± 41.07b</td>
<td>1162.00 ± 7.21°</td>
<td>789.00 ± 45.31°</td>
<td>2525.33 ± 53.53°</td>
<td>1363.33 ± 60.01°</td>
<td>6.18 ± 0.08°</td>
<td>82.60 ± 0.39°</td>
</tr>
<tr>
<td>50TBS/50WS</td>
<td>1837.67 ± 23.18b</td>
<td>1149.67 ± 17.21b</td>
<td>688.00 ± 6.08°</td>
<td>2472.00 ± 41.04°</td>
<td>1322.33 ± 42.83°</td>
<td>5.60 ± 0.07°</td>
<td>78.80 ± 0.35°</td>
</tr>
<tr>
<td>100 TBS</td>
<td>1966.33 ± 12.03</td>
<td>1568.77 ± 67.663</td>
<td>1198.33 ± 60.12</td>
<td>2403.33 ± 139.88</td>
<td>2485.33 ± 79.21</td>
<td>4.13 ± 0.07°</td>
<td>69.10 ± 0.39°</td>
</tr>
</tbody>
</table>

Means carrying same letters in columns are statistically non significant.

Table 3. Texture parameters of starch blends.

<table>
<thead>
<tr>
<th>Blends</th>
<th>Hardness (g)</th>
<th>Cohesiveness</th>
<th>Springiness (mm)</th>
<th>Adhesiveness (mJ)</th>
<th>Gumminess (g)</th>
<th>Chewiness (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100WS</td>
<td>166.50 ± 7.78°</td>
<td>0.56 ± 0.16°</td>
<td>10.30 ± 0.28°</td>
<td>1.50 ± 0.42°</td>
<td>93.24 ± 21.55°</td>
<td>960.37 ± 248.12°</td>
</tr>
<tr>
<td>10TBS/90WS</td>
<td>163.00 ± 4.24°</td>
<td>0.50 ± 0.01°</td>
<td>9.95 ± 0.49°</td>
<td>1.25 ± 0.07°</td>
<td>80.69 ± 3.25°</td>
<td>802.82 ± 72.31°</td>
</tr>
<tr>
<td>30TBS/70WS</td>
<td>205.00 ± 7.07°</td>
<td>0.50 ± 0.03°</td>
<td>9.10 ± 0.14°</td>
<td>1.05 ± 0.21°</td>
<td>102.50 ± 7.07°</td>
<td>932.75 ± 6.11°</td>
</tr>
<tr>
<td>50TBS/50WS</td>
<td>220.00 ± 2.83°</td>
<td>0.55 ± 0.11°</td>
<td>9.00 ± 0.85°</td>
<td>1.45 ± 0.35°</td>
<td>122.1 ± 23.56°</td>
<td>1098.9 ± 315.52°</td>
</tr>
<tr>
<td>100 TBS</td>
<td>736 ± 9.90°</td>
<td>0.36 ± 0.05°</td>
<td>8.10 ± 0.71°</td>
<td>2.55 ± 0.35°</td>
<td>261.28 ± 32.92°</td>
<td>2116.37 ± 82.04°</td>
</tr>
</tbody>
</table>

Means carrying same letters in rows are statistically non significant.
corresponding mixtures are presented in Table 3. The TBS gel was harder than WS, while cohesiveness and springiness of WS was higher than that of TBS. Gel hardness was significantly increased as the level of TBS was increased in WS. Amylose content of a starch is considered to be a factor determining the gel hardness. (Sandhu et al., 2010) reported that due to less amylose contents, rice starch has lower hardness as compared to potato starch. Miles et al., (1985) explained that retrogradation of starch gels associated with water syneresis and crystallization of amylopectin results in gel firmness. The results presented in Fig. 3 showing syneresis from starch gels also explains this phenomenon. Increase in gel hardness in starch blends with increase in the levels of TBS in WS can be attributed to higher amylose contents of TBS (52.5%) (Grelda et al., 1997) as compared to WS (26.7%) (Kim and Hill, 1984). Cohesiveness of gels from individual WS, TBS and their blends ranged between 0.36 ± 0.05 to 0.56 ± 0.16. The influence of WS on cohesiveness was higher in (50/50) WS: TBS blend as compared to TBS. The cohesiveness value of the 50/50 blends was 0.55 ± 0.11 which was almost the same i.e 0.56 ± 0.16 to WS. Higher degree of polymerization of amylose fraction may results in higher cohesiveness values (Walldt and Khoe, 1959; Sandhu et al., 2010). According to Novelo-Cen and Betancur-Ancona (2005), more firm and rigid gels as observed in our studies (e.g 30/70 and 50/50 WS: TBS) can be used in different products like puddings, custards and creams.

Syneresis  Syneresis studies were carried on different starch gels to determine the freeze thaw stability. During the storage and transportation of frozen foods, there is a possibility of thawing and re freezing. The possible effects of these repeated freezing and thawing phenomenon results in the formation of large ice crystals that can damage the overall structure of foods. The freeze-thaw stability of different foods depends on factors like temperature and length of storage period. The syneresis from individual starches and their blends at 1, 30 and 60 days intervals are represented in Fig. 3. It can be clearly observed that overall, during all storage periods, TBS showed higher degree of syneresis as compared to WS. The syneresis in all the blends linearly increased as the level of TBS in WS was increased. This could be attributed due to higher amount of amylose contents in TBS as compared to WS. Amylose is unstable in water and it expels water during the retrogradation. Amylose instability in the system is due to intermolecular attraction and association of neighboring amylose molecules. This leads to an increase in viscosity, retrogradation, and under specific conditions, precipitation of amylose particles by expelling the water from the system (Tester et al., 2004; Zobel 1984 ). Addition of lima bean starch in cassava starch also supports our studies, as more syneresis was observed when level of lima bean (high amylose content) starch was increased in blends made with low amylose containing cassava starch (Novelo-Cen and Betancur-Ancona, 2005). It was also noticed that; syneresis at day 1 storage was lower, which was increased significantly at 30 days storage. This can be due to the reason that after first freeze-thaw cycle at day 1, same gel was restored for 30 days storage and syneresis was carried out on the same gel. The initial thawing (day 1) might have disturbed the gel structure and facilitated the syneresis from the gel after 30 days. But the syneresis from gels was again reduced after 60 days storage which can be attributed to the presence of relatively less amount of water in gel structure as compared to first two storage intervals. It is obvious from the current studies that individual TBS might not be a good choice due to higher retrogradation due to syneresis in foods like breads, soups, cakes and puddings but blending it with WS can be helpful to get a control over this problem.

Light microscopy  Light microscopic images showing cooked or uncooked TBS and WS starch and their different mixtures are presented in Fig. 4. As shown in Figure, WS uncooked sample (a) represents large and small types of round granules. TBS uncooked starch granules (b) also exhibited two sizes and characterized as oval shape. Turkish bean granules are relatively larger than that of wheat granules (a and b). Mixed images due to additive effect of both starches were clearly observed which was dependent on the blending proportions. As the level of TBS starch was increased (e, f, g) respectively, the dominance of TBS in the gel network is clearly evident. This is the indication that how significantly TBS starch has influenced the starch paste properties as compared to wheat starch.
Fig. 4. Light microscopic images of starch gels (40× magnification).

a. Wheat Starch uncooked  
b. Turkish bean starch uncooked  
c. Wheat Starch cooked  
d. Turkish bean starch cooked  
e. Wheat-Turkish starches (90 − 10) cooked  
f. Wheat-Turkish starches (70 − 30) cooked  
g. Wheat-Turkish starches (50 − 50) cooked
Conclusion

The results of present work indicate that blending of wheat and Turkish bean starch can help to produce the gels with different acceptable rheological properties. The presence of interaction between the different starches is also observed during thermal analysis conducted on differential scanning colorimeter. The textural properties were more affected by Turkish bean starch when blending was done in equal proportions. Overall, blending of starches did not show any negative effect on different properties. Based on the results of studies, it can be recommended that the blending of these starches make possible to get the optimal characteristic for using in baby foods, soups, and puddings.

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