

Impact of Sodium Chloride and Ascorbic Acid on Pasting and Textural Parameters of Corn Starch-Water and Milk Systems

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Abstract

The effect of NaCl and ascorbic acid addition at the different concentrations on the pasting and textural parameters of corn starch in water and skimmed milk were determined using Texture and Rapid Visco Analyser. Rapid Visco analysis exhibited that addition of NaCl and ascorbic acid significantly affected ($p<0.05$) the pasting parameters such as peak time, pasting temperature, peak, breakdown, final, trough and setback viscosities. Also addition of NaCl and ascorbic acid significantly influenced ($p<0.05$) textural properties such as hardness, adhesiveness, springiness, cohesiveness, chewiness, gumminess, and resilience values of starch gels. This study indicated that the concentration ratio was found to be quite significant in the addition of salt and ascorbic acid to the corn starch. These results will be used as a guideline in the development of starch-based food products containing NaCl and ascorbic acid.

Keywords: Corn starch, Salt, Ascorbic acid, Texture profile analysis (TPA), Rapid Visco Analyser (RVA)

INTRODUCTION

Starch, the main carbohydrate storage form in green plants, is mainly found in seeds, tubers, roots, leaves, stems and fruits (Ai & Jane, 2015). The reason for common use of starch is related to the gelling and thickening agent in food industry. Starch is extensively used as a thickening agent in dairy-based jellies, sauces, sweets, custards and desserts (Abu-Jdayil et al., 2004).

In various food systems, the starch/polysaccharides mixtures of co-existing with salt, ascorbic acid and other ingredients (Feng et al., 2016). Among these food ingredients, ascorbic acid is naturally present in vegetables and fruits or added to regulate pH, inhibition of microbial growth (Majzoobi et al., 2014). On the other hand, salts are generally used in starch products as a condiment. In yellow alkaline noodles and sauce, both salt and starch are essential components of the formula (Wang et al., 2016). Also, it is known that the addition of salt and ascorbic acid significantly effect the rheological and pasting characteristics of various starch gels (Katsuta, 1998; Ahmad & Williams, 1999; Chiotelli et al., 2002; Hirashima et al., 2005; Samutsri & Suphantharika, 2012). Although there has been some information on the addition of salt and ascorbic acid of different starch types, no literature was found associated with the effect of NaCl and ascorbic acid concentration on pasting and textural characteristics of corn starch-water and milk gel. Therefore, the main aim of this research was to elucidate the impact of NaCl and ascorbic acid concentration on pasting and textural parameters of corn starch-water and milk systems. It will provide the information for preparation of starch-based products with NaCl and ascorbic acid.

MATERIALS AND METHODS

Materials

Corn starch (Selva Food Industry Inc., Turkey), UHT skimmed milk (Pınar Dairy Products Inc., Turkey), L(+) ascorbic acid (Merck, Darmstadt, Germany), NaCl (Merck, Darmstadt, Germany) and distilled water were used in the current study.

Methods

Pasting parameters

In this study, the impact of NaCl and ascorbic acid at different concentrations on the pasting properties of corn starch-water and milk systems were investigated using Rapid Visco Analyser (RVA) (Perten RVA 4500; Perten Instruments, Warriewood, NSW, Australia). Approximately, 3 g NaCl and corn starch or ascorbic acid and corn starch mixture were put into RVA canister. Subsequently, 25 ml water or skimmed milk was added, the mixture was heated 50 °C and stirring at 50 °C at 160 rpm for 10 s. The samples were held at 50 °C for 1 min., heated to 95 °C at 13.16 °C/min, kept at 95 °C for 5 min and were cooled to 50 °C at 7.28 °C/min. Thermocline windows software (Perten) was used to calculate pasting parameters (pasting temperature, peak time, peak, breakdown, trough, final and setback viscosities).

Textural parameters

According to the method described by Yildiz et al (2013) the impact of NaCl and ascorbic acid concentration on texture profile analysis (TPA) of corn starch gels in water and skimmed milk was carried out by using texture analyser (TAXT2i; Stable Micro Systems Ltd., Godalming, UK) equipped with a P/25 cylindrical probe and load cell of 5 kg was used. Deformation distance, test speed and trigger force were adjusted to 5 mm, 1 mm/s and 5 g, respectively.

Hardness, springiness, adhesiveness, cohesiveness, gumminess, chewiness and resilience were supplied from TPA by using texture instrument software (version 2.0.7.0; Stable Microsystems, Godalming, UK). For each sample, all measurements were carried out three times.

Statistical analysis

Concentrations of corn starch samples were recorded as a mean±standard deviation of triplicate measurements. ANOVA was conducted using SPSS (SPSS Statistics V.20; Armonk, NY, USA) to determine the effect of NaCl and ascorbic acid concentration on the pasting and textural parameters of corn starch was significant or not. Also, for comparison of corn starch-ascorbic acid-water and corn starch-ascorbic acid-skimmed milk or corn starch-NaCl-water and corn starch-NaCl-skimmed milk groups, t test were used.

RESULTS AND DISCUSSIONS

Impact of NaCl and ascorbic acid concentrations on pasting parameters of corn starch- water and skimmed milk mixture

Pasting parameters of the corn starch in water and skimmed milk including NaCl and ascorbic acid in different concentrations are seen in Table 1. The addition of NaCl and ascorbic acid in different concentrations significantly affected ($P<0.05$) peak viscosity (PV) of corn starch-water and milk. Also, a significant difference ($P<0.05$) was determined by the addition of NaCl and ascorbic acid between corn starches prepared in water and prepared in milk. In addition, corn starch in skimmed milk showed higher PV than the samples prepared using water. Similarly, Matser and Steeneken (1997) determined that the viscosity of a certain concentration of starch-milk mixture is higher than the viscosity of that same concentration in water. It is thought to be this situation is related to the particle rigidity of starch-skim milk mixture was higher than starch-water (Abu-Jdayil, 2004). When the data compared with the literature, our results were higher than the value determined by Sandhu and Singh (2007) and Gani et al. (2014).

Trough viscosity (TV) of corn starch-water and milk values ranged between from 1814 to 1557.50 cP, 2769.50 to 2417 cP, respectively. As shown in Table 1, it was determined that TV values of a certain concentration of corn starch-water mixture were lower than the TV of that same concentration in water. The presence of naturally occurring cations in milk, such as Ca^{+2} , Mg^{+2} , Na^{+} and K^{+} promotes a network formation between the gellan molecules. This network may connect with the starch granule, delaying amylose leaching and swelling. In addition to the cations, the interaction of milk proteins with starch may also have contributed to the increased viscosity (Coronato et al., 2012).

Final viscosity (FV) and breakdown viscosity (BV) of corn starch-water and corn starch-milk values changed between from 2719 to 4863.50 cP, 872.50 to 1828.50 cP, respectively. FV values of these studies were similar, but BV values were lower than the value determined by Ahmad Mir et al. (2017) for corn cultivars. As seen from Table 1, it was determined that ascorbic acid added corn starch had higher FV and

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BV than salt added starches. In general, it has been found that the addition of ascorbic acid to corn starch samples increased the BV value. But, the addition of 0.4% ascorbic acid resulted in a greater reduction in BV content of corn starch in water. Our results were similar to Trithavisup and Charoenrein (2016), who found that the addition of ascorbic acid increased the BV viscosity. Also, FV and SV of corn starch samples generally significantly decreased ($P < 0.05$). The reduction in the SV (retrogradation) can be due to interactions between starch chains and some amino acids. Therefore, the reduction in the content of amylose may contribute to the reduction of retrogradation (Ziegler et al., 2018).

In the present study, PaT for corn starches changed between 76.58 and 81.50 °C, the lowest shown by ascorbic acid added corn starch in water and the highest by NaCl added corn starch in skimmed milk. Similarly, Seetharaman et al. (2001) determined PaT in the range of 74.9–84.7 °C for corn landraces of Argentinian. The addition of NaCl and ascorbic acid increased the pasting temperature (PaT) of corn starch with an increase in concentration. The higher PaT has shown the potential for resistance to swelling in the content (Kumar et al., 2018). The ability of the salts to change the gelatinisation temperature of the starch is linked to the effect on the structures of water. Powerful hydrated ions increase the structural sequence of water with reduced ability of gelatinized starch. Conversely, weakly hydrated ions disrupt the water structure and assist gelatinization. The chloride ion is placed in the middle of the lyotropic series and therefore has little effect on the structure of water (Jyothi et al., 2005).

As seen in table 1, the peak time values of corn starches showed irregular change. PeT values of corn starch-water mixture and corn starch-skimmed milk ranged from 4.96 to 5.19 min, 4.95 to 5.33 min, respectively.

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Table 1. Impact of NaCl and ascorbic acid addition at the different concentration on the pasting parameters of corn starch in water and skimmed milk (mean±standart deviations)
 For ascorbic acid and NaCl, Mean values shown by different letters (a-d) show differences between the concentrations ($P<0.05$),
 For the same ingredient, Mean values in the same column shown different letters (A-B) between the water and skimmed milk ($P <0.05$),
 PV: Peak viscosity, TV: Trough viscosity, BV: Breakdown viscosity, FV: Final viscosity, SV:Setback viscosity, PeT:Peak time, PaT: Pasting temperature

	Ingredient	Conc.	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PeT (min)	PaT (°C)
		(%)							
Water	Ascorbic acid	0	2701.50±2.12 ^{bA}	1814.00±19.8 ^{cA}	872.50±3.54 ^{aA}	3044.50±62.93 ^{cA}	1255.50±7.78 ^{cA}	5.13±0.01 ^{bA}	76.75±0.00 ^{aA}
		0.1	2465.00±21.21 ^{aA}	1557.50±10.61 ^{aA}	907.50±10.61 ^{bA}	2786.00±8.49 ^{aA}	1223.50±4.95 ^{bA}	5.12±0.02 ^{bA}	76.73±0.04 ^{aA}
		0.2	2855.50±7.77 ^{dA}	1685.00±7.07 ^{bA}	1160.50±14.85 ^{dA}	3152.50±3.54 ^{dA}	1462.50±3.54 ^{cA}	5.06±0.02 ^{abA}	76.58±0.11 ^{aA}
		0.3	2769.00±26.87 ^{cA}	1588.50±19.09 ^{aA}	1183.00±4.24 ^{cA}	2999.00±5.66 ^{cA}	1400.50±0.71 ^{dA}	4.96±0.06 ^{aA}	76.68±0.11 ^{aA}
		0.4	2710.00±14.14 ^{bA}	1717.00±24.04 ^{bA}	983.00±4.24 ^{cA}	2917.50±24.75 ^{bA}	1191.00±14.14 ^{aA}	5.04±0.05 ^{abA}	76.63±0.04 ^{aA}
	NaCl	0	2701.50±2.12 ^{cA}	1814.00±19.8 ^{bA}	872.50±3.54 ^{cA}	3044.50±62.93 ^{dA}	1255.50±7.78 ^{cA}	5.13±0.01 ^{bA}	76.75±0.00 ^{aA}
		1	2676.00±36.76 ^{cA}	1730.00±21.21 ^{aA}	953.50±4.95 ^{cA}	2948.00±11.31 ^{cA}	1205.50±7.78 ^{dA}	5.05±0.03 ^{aA}	77.20±0.28 ^{bA}
		2	2641.00±57.98 ^{cA}	1740.00±42.43 ^{aA}	911.00±1.41 ^{dA}	2874.00±28.28 ^{cA}	1122.00±2.83 ^{cA}	5.12±0.02 ^{bA}	79.19±0.01 ^{cA}
		3	2541.50±2.12 ^{bA}	1770.00±7.07 ^{abA}	758.00±14.14 ^{bA}	2719.00±21.21 ^{bA}	954.00±7.07 ^{bA}	5.19±0.01 ^{cA}	79.85±0.14 ^{dA}
		4	2451.00±7.07 ^{aA}	1774.00±5.66 ^{abA}	674.00±5.66 ^{aA}	2633.00±4.24 ^{aA}	854.00±5.66 ^{aA}	5.19±0.01 ^{cA}	79.85±0.14 ^{dA}
Skimmed milk	Ascorbic acid	0	4041.50±58.69 ^{ab}	2709.00±12.73 ^{bb}	1360.00±7.07 ^{bb}	4808.50±12.02 ^{db}	2049.50±70 ^{cb}	5.33±0.00 ^{cb}	79.08±0.11 ^{ab}
		0.1	4227.00±38.18 ^{bb}	2769.50±27.58 ^{cb}	1457.50±10.61 ^{bb}	4863.50±19.09 ^{eb}	2069.00±26.87 ^{cb}	5.30±0.04 ^{cA}	79.14±0.01 ^{ab}
		0.2	4234.00±5.66 ^{bb}	2645.50±7.78 ^{bb}	1568.50±26.16 ^{cb}	4640.00±14.14 ^{cb}	1994.50±6.36 ^{cb}	5.18±0.04 ^{bA}	79.19±0.01 ^{ab}
		0.3	4266.00±22.63 ^{bb}	2659.50±13.44 ^{ab}	1611.50±2.12 ^{db}	4564.00±5.66 ^{bb}	1894.50±6.36 ^{bb}	5.24±0.04 ^{bcB}	79.95±0.07 ^{bb}
		0.4	4522.00±9.90 ^{cb}	2686.00±8.49 ^{abB}	1828.50±12.02 ^{cb}	4489.00±19.8 ^{ab}	1805.50±7.78 ^{ab}	4.95±0.07 ^{aA}	79.93±0.04 ^{bb}
	NaCl	0	4041.50±58.69 ^{bb}	2709.00±12.73 ^{db}	1360.00±7.07 ^{bb}	4808.50±12.02 ^{db}	2049.50±70 ^{cb}	5.33±0.00 ^{bb}	79.08±0.11 ^{ab}
		1	4341.00±57.98 ^{cb}	2725.00±35.36 ^{db}	1616.00±22.63 ^{db}	4729.00±41.01 ^{cb}	2004.50±4.95 ^{cb}	5.06±0.01 ^{aA}	79.93±0.04 ^{bb}
		2	4017.00±24.04 ^{bb}	2518.00±11.31 ^{bb}	1504.00±5.66 ^{cb}	4408.00±7.07 ^{bb}	1868.50±26.16 ^{bb}	5.06±0.02 ^{aA}	80.65±0.28 ^{cA}
		3	4069.50±20.51 ^{bb}	2603.50±4.95 ^{cb}	1512.00±49.50 ^{cb}	4422.00±2.83 ^{bb}	1812.00±7.07 ^{bb}	5.06±0.02 ^{ab}	80.55±0.21 ^{cA}
		4	3645.00±14.14 ^{ab}	2417.00±7.07 ^{bb}	1222.50±14.85 ^{ab}	4006.50±9.19 ^{ab}	1586.00±7.07 ^{ab}	5.06±0.02 ^{ab}	81.50±0.14 ^{db}

Impact of NaCl and ascorbic acid concentrations on textural parameters of corn starch- water and skimmed milk mixture

The effect of NaCl and ascorbic acid addition at different concentrations on the textural parameters of corn starch in water and skimmed milk are shown in Table 2. Hardness values of corn starch-water and milk system changed irregular with the addition of NaCl and ascorbic acid at different concentrations. However, the addition of NaCl and ascorbic acid affected the hardness value of corn starch gels significantly ($P<0.05$). It seemed that there were critical levels of NaCl concentration for hardness of the mixed gels. Feng et al. (2016) determined that when NaCl concentration is below the critical value, the hardness value increases. In contrast, when NaCl concentration is above the critical value, the hardness value decreases. Therefore, the addition of NaCl at appropriate concentration can improve the hardness of the corn starch-water and milk gels. In our study, similar results were determined with the addition of ascorbic acid at different concentrations.

The addition of NaCl and ascorbic acid significantly affected ($P<0.05$) the adhesiveness values of gel samples. Adhesiveness (g.s) values of corn starch-water and milk gels were changed between -67.69 and -396.48, -506.02 and -988.57, respectively. The adhesiveness of the starch-milk mixture is higher values than the adhesiveness of that same concentration in water. Our results were higher than the value determined by Sandhu and Singh (2007) for corn starch gels.

Springiness values of corn starch-water and skimmed milk systems changed between 0.98 to 3.42 mm, 0.80 to 0.98 mm, respectively. The springiness of corn starch-milk mixture is lower values than the springiness of corn starch-water mixture. It is thought to be this situation is related to the viscosity of a certain concentration of starch-milk mixture is higher than the viscosity of that same concentration in water.

Cohesiveness is related to the internal structure of the sample, which represents the degree of difficulty that occurred while breaking down the internal structure of the sample. In addition to elasticity and viscosity of the sample, it contains both the cohesive and adhesive forces (Yildiz et al., 2015). The cohesiveness value of the samples ranged between 0.43 and 0.86.

Another textural parameter of corn starch samples determined from TPA analysis is gumminess characterizes semi-solid foods with high degree of cohesiveness and a low degree of hardness. Gumminess is defined as the product of cohesiveness and hardness (Erim Köse et al., 2018). Gumminess value of the corn starch-water and skimmed milk samples changed between 41.97 and 1610.29.

The chewiness is calculated by multiplying hardness with springiness and cohesiveness and it is known as the energy required to masticate a solid food to a state ready for swallowing (Yildiz et al., 2015). As seen Table 2, the addition of NaCl and ascorbic acid affected the chewiness value of corn starch gels significantly ($P<0.05$). In general, the chewiness of starch-milk mixture is lower values than the chewiness of that same concentration in water. As above mention, chewiness values of corn starch-water and milk system changed irregular with the addition of NaCl and ascorbic acid at different concentrations. The increase or decrease in chewiness as NaCl and ascorbic acid content increased could be due to the increase or decrease in hardness as NaCl and ascorbic acid concentration increased since the formula used to calculate chewiness is known as the multiplication of hardness with springiness and cohesiveness.

The other textural parameter determined in this study for corn starch-water and milk mixture is resilience. The resilience value of corn starch samples changed between 0.11 and 0.17.

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Table 2. Impact of NaCl and ascorbic acid addition at the different concentration on the textural parameters of corn starch in water and skimmed milk (mean±standart deviations) For ascorbic acid and NaCl, Mean values shown by different letters (a-d) show differences between the concentrations ($P < 0.05$), For the same ingredient, Mean values in the same column shown different letters (A-B) between the water and skimmed milk ($P < 0.05$), PV: Peak viscosity, TV: Trough viscosity, BV: Breakdown viscosity, FV: Final viscosity, SV:Setback viscosity, PeT:Peak time, PaT: Pasting temperature

Ingredient	Conc.(%)	Hardness (g)	Adhesiveness (g s)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g mm)	Resilience	
				(mm)					
Water	Ascorbic acid	0	1334.23±5.98 ^{bA}	-196.16±1.64 ^{dA}	1.00±0.00 ^{aA}	0.53±0.01 ^{aA}	705.98±1.39 ^{cA}	701.73±2.45 ^{bA}	0.15±0.00 ^{dA}
		0.1	74.46±20.44 ^{aA}	-358.24±14.19 ^{aA}	3.42±0.02 ^{dA}	0.47±0.03 ^{aA}	41.97±2.78 ^{aA}	145.67±7.15 ^{aA}	0.11±0.00 ^{aA}
		0.2	1438.13±17.78 ^{cA}	-292.08±14.13 ^{bA}	3.19±0.04 ^{cA}	0.46±0.04 ^{aA}	693.22±4.24 ^{bA}	2233.29±7.47 ^{dA}	0.14±0.00 ^{cA}
		0.3	1538.57±18.48 ^{dA}	-279.01±12.74 ^{cA}	1.49±0.04 ^{bA}	0.53±0.04 ^{aA}	847.47±3.11 ^{dA}	1273.99±6.70 ^{cA}	0.13±0.00 ^{bA}
		0.4	1318.19±13.44 ^{bA}	-314.60±14.14 ^{bA}	0.98±0.04 ^{aA}	0.52±0.02 ^{aA}	701.87±2.64 ^{cA}	695.18±7.18 ^{bA}	0.13±0.00 ^{bA}
	NaCl	0	1334.23±5.98 ^{bA}	-196.16±1.64 ^{dA}	1.00±0.00 ^{aA}	0.53±0.01 ^{bA}	705.98±1.39 ^{cA}	701.73±2.45 ^{cA}	0.15±0.00 ^{bA}
		1	2007.68±10.85 ^{dA}	-67.69±3.80 ^{eA}	1.00±0.01 ^{aA}	0.44±0.00 ^{aA}	892.93±3.78 ^{eA}	885.59±7.90 ^{eA}	0.16±0.00 ^{cA}
		2	330.16±21.23 ^{aA}	-396.48±9.16 ^{aA}	0.99±0.01 ^{aA}	0.53±0.04 ^{bA}	190.142.69 ^{bA}	664.27±7.10 ^{bA}	0.11±0.00 ^{aA}
		3	347.15±21.21 ^{aA}	-272.22±14.45 ^{bA}	1.00±0.01 ^{aA}	0.43±0.04 ^{aA}	162.753.61 ^{aA}	159.37±7.23 ^{aA}	0.11±0.00 ^{aA}
		4	1837.21±49.50 ^{cA}	-248.22±7.10 ^{cA}	1.00±0.01 ^{aA}	0.43±0.04 ^{aA}	802.603.68 ^{dA}	795.61±7.93 ^{dA}	0.11±0.00 ^{aA}
Skimmed milk	Ascorbic acid	0	870.12±0.16 ^{bB}	-576.48±2.09 ^{cB}	0.80±0.00 ^{aB}	0.51±0.01 ^{aA}	431.37±1.94 ^{bB}	346.03±1.45 ^{bB}	0.16±0.00 ^{bA}
		0.10	224.06±19.88 ^{aB}	-767.07±14.14 ^{bB}	0.93±0.04 ^{bB}	0.55±0.04 ^{abA}	134.95±3.54 ^{aB}	125.98±6.59 ^{aA}	0.15±0.00 ^{aB}
		0.20	866.38±21.32 ^{bB}	-864.30±14.23 ^{aB}	0.92±0.03 ^{bB}	0.59±0.03 ^{abA}	538.52±3.54 ^{cB}	503.82±5.26 ^{cB}	0.15±0.00 ^{aA}
		0.30	1823.31±14.23 ^{cB}	-530.06±14.16 ^{dB}	0.93±0.04 ^{bB}	0.86±0.04 ^{cB}	1610.29±2.84 ^{eB}	1527.36±7.23 ^{eB}	0.16±0.00 ^{bB}
		0.40	2033.03±14.18 ^{dB}	-838.71±11.58 ^{aB}	0.92±0.02 ^{bA}	0.64±0.04 ^{bA}	1339.32±3.54 ^{dB}	1247.18±7.04 ^{dB}	0.17±0.01 ^{bA}
	NaCl	0	870.12±0.16 ^{dB}	-576.48±2.09 ^{dB}	0.80±0.00 ^{aB}	0.51±0.01 ^{aA}	431.37±1.94 ^{dB}	346.03±1.45 ^{cB}	0.16±0.00 ^{dA}
		1	1016.60±23.02 ^{eB}	-809.45±13.07 ^{bB}	0.96±0.01 ^{bB}	0.70±0.03 ^{bB}	742.22±3.13 ^{eB}	708.05±7.14 ^{dB}	0.15±0.00 ^{cB}
		2	517.14±21.06 ^{bB}	-988.57±12.11 ^{aB}	0.93±0.00 ^{bA}	0.57±0.03 ^{aA}	312.93±3.57 ^{bB}	289.31±7.16 ^{bB}	0.14±0.00 ^{bB}
		3	116.38±22.71 ^{aB}	-622.29±14.26 ^{cB}	0.93±0.04 ^{bB}	0.81±0.04 ^{cB}	107.52±2.83 ^{aB}	100.22±7.02 ^{aB}	0.15±0.00 ^{cB}
		4	595.92±28.38 ^{cB}	-506.02±8.51 ^{eB}	0.98±0.00 ^{bB}	0.55±0.04 ^{aA}	345.89±3.68 ^{cB}	335.92±8.01 ^{cB}	0.13±0.01 ^{aA}

CONCLUSION

This investigation showed that the addition of NaCl and ascorbic acid have a significant effect on the pasting and textural properties of corn starch/water or corn starch/skimmed milk combined systems and addition of NaCl and ascorbic acid at different concentrations giving rise to irregular change. The studied corn starch-water or corn starch-skimmed milk with ascorbic acid and NaCl could be used in many different food products and process optimisation to change its pasting and textural parameters. The concentration of NaCl and ascorbic acid could be selected depending on the quality characteristics of the product and production processes. For these reasons, further studies are needed to demonstrate the relationship between corn starch and different starches with water, milk and milk components.

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