Pasting properties of buckwheat, rice and maize flours and textural properties of their gels: effect of ascorbic acid concentration

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Abstract

In the present study, the effect of ascorbic acid addition on the pasting properties of several gluten-free flours, namely buckwheat, maize and rice flours, and textural properties of their gels were also investigated. Pasting curves of control flour and 10 mg/kg ascorbic acid-including flour were found to be very similar to each other. However, higher levels of ascorbic acid significantly influenced the magnitude of all pasting parameters such as peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature. Regarding textural properties specifying machinability of the doughs, ascorbic acid addition also generally influenced textural characteristics such as hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience parameters of the samples. According to the results, the ascorbic acid level to be used with the gluten-free flour should be adjusted carefully with regard to pasting and textural parameters. Ascorbic acid addition level directly affected the quality of the end products, determining consumer preference.

Keywords: gluten-free, ascorbic acid, pasting properties, textural properties, gels

1. Introduction

In the milling and baking industries, several food additives are widely used for improving the quality by overcoming the deficiencies resulted from composition and characteristics of flour and for increasing operational efficiencies by saving time and labour. Oxidants, reducing and antistaling agents, enzymes, surfactants and emulsifiers are widespread additives added to bakery products (Elgün and Ertugay, 1995; Kim and Walker, 1992; Ryu and Walker, 1993) to manufacture the end products with desired quality. Moreover, sugar and different sweeteners, fats and oils, additives rich in proteins (milk powder, whey protein, soybean flour, etc.) are also added to the formulation for different purposes (Elgün and Ertugay, 1995).

Among those additives, L-ascorbic acid, as known, which are naturally present in many vegetables and fruits and due to its antioxidant activity it is added to formulations of various food products. The reason of common usage of ascorbic acid is also associated with its cheapness, safety to eat, and environment-friendly characteristics (Guo *et al.*, 2012). If we look from the viewpoint of the baking industry, bakery products are supplemented with ascorbic acid up to 200 mg per kg wheat flour for improving the viscoelastic characteristics of bread quality (Pomeranz, 1984). Nowadays, for most countries (including Turkey), only L-ascorbic acid is permitted as oxidants in most of the bakery products (Bahar, 2001).

Ascorbic acid can be used as an oxidative or a reducing agent depending on the conditions of the system to which ascorbic acid is added. The oxidative influence of ascorbic acid on wheat gluten properties was investigated and it was reported that ascorbic acid leads to an improvement in strength and stability of dough. Therefore, it is favoured to utilise ascorbic acid with weak flour in order to improve their baking characteristics. Ascorbic acid can behave as a reducing agent by reducing disulfide bonds present in the gluten network under vacuum conditions, such as vacuum mixers which can debilitate the dough structure. Such characteristics of ascorbic acid may provide an advantage in terms of improving the machinability of dough (Pomeranz, 1984). In recent years tendency of researchers to carry out the studies related with gluten-free products for improvement diet of people with celiac disease, it is required to investigate the effect of ascorbic acid on the some important quality characteristics of gluten-free flours. Usage possibilities of ascorbic acid in gluten-free products in terms of pasting and textural characteristics should be determined.

Although the influence of ascorbic acid addition on pasting properties of wheat flour and different starches was investigated in previous studies (Majzoobi *et. al.*, 2012; Sriburi *et al.*, 1999), no sufficient study was performed about the influence of it on the pasting properties of rice flour (Guo *et al.*, 2012; Wu *et al.*, 2010). We also have not encountered any studies for the observation of ascorbic acid´s effect on the pasting properties of maize and buckwheat flours. As mostly used flour types alternative to wheat flour, these flours are widely used in the formulation of several gluten-free products (Gularte *et al.*, 2012; Lazaridou *et al.*, 2007; Levent and Bilgiçli, 2011; Lopez *et al.*, 2004; Ronda *et al.*, 2009; Sanchez *et al.*, 2002; Shih *et al.*, 2006; Witczak *et al.*, 2012; Yildiz and Bulut, 2016). Determination of pasting properties of flours and starches, and textural properties of their gels are significant because of their roles in baking and eating characteristics of the bakery products.

Therefore, the objective of the present study was to investigate the effect of ascorbic acid addition levels on the pasting properties of maize, rice and buckwheat flours and textural properties of the obtained gels. As mentioned above the findings of the present study could provide an insight about probable usage of ascorbic acid in gluten-free products.

2. Materials and methods

Materials

In this study, buckwheat (Fitmek, Hedef Gluten-free Industry and Trade Inc., Izmir, Turkey), maize and rice flours (Aro-Tech, Food Industry and Trade Inc., Istanbul, Turkey) and ascorbic acid (Adler, KMK Laboratories Food Additives Industry and Trade Co. Ltd., Istanbul, Turkey) were used in the study.

Methods

Pasting properties

In this study, ascorbic acid was added to buckwheat, maize and rice flours in concentrations of 10, 30, 50 and 100 mg/kg (flour weight bases) and pasting properties of the flours were determined using a rapid visco-analyser (RVA) (Perten RVA 4500; Perten Instruments, Warriewood, NSW, Australia). Totally 3 g ascorbic acid and flour blend was put into aluminium canisters. After addition of 25 ml of water, the analysis was started immediately. The prepared mixture was heated to 50 °C and after stirring at that temperature at 160 rpm for 10 s, the samples were held at 50 °C for 1 min. Then, the samples were heated to 95 °C at 13.16 °C/min and held at that temperature for 5 min. Next, the samples were cooled down to again 50 °C at 7.28 °C/min. Corresponding pasting parameters, namely peak viscosity (PV), trough viscosity (TV), breakdown viscosity (BV), final viscosity (FV), setback viscosity (SV), peak time (PeT) and pasting temperature (PaT) were determined using time versus viscosity curve obtained. The Thermocline windows software (Perten) was used to calculate the corresponding parameters mentioned above. The RVA analysis for each ascorbic acid/flour blend was repeated three times.

Textural properties

The influence of ascorbic acid at the concentrations of 10, 30, 50 and 100 mg/kg on the textural properties of gels prepared by buckwheat, maize and rice flours was also investigated in this study. Texture profile analysis (TPA) was conducted according to the method described by Yildiz *et al.* (2013). Prior to analysis, the prepared gels were stored at room temperature for 3 hours in canisters covered with parafilm. The texture profile analysis was carried out by a texture analyser (TAXT2i; Stable Micro Systems Ltd., Godalming, UK). A load cell of 5 kg and a P/25 cylindrical probe was used in the textural measurement. Trigger force, test speed and deformation distance were adjusted to 5 g, 1 mm/s and 5 mm, respectively. The measurements were replicated 5 times. TPA parameters (hardness, adhesiveness, cohesiveness, gumminess, chewiness, springiness and resilience) of the gels were calculated using time versus force data obtained from Texture Exponent software (version 2.0.7.0; Stable Microsystems, Godalming, UK).

Statistical analyses

The results were expressed as mean ± standard deviation. ANOVA was conducted using SPSS (SPSS Statistics 17.0; Armonk, NY, USA) to determine if the effect of ascorbic acid concentration on the pasting properties of gluten-free flour and textural properties of their gels was significant or not.

3. Results and discussion

Effect of ascorbic acid concentration on pasting properties of the flour

The effect of ascorbic acid addition at different concentrations (10, 30, 50 and 100 mg/kg) on the pasting curves of the buckwheat flour is presented in Figure 1. It illustrates that pasting behaviour of the control and the other sample including ascorbic acid at concentration of 10 mg/kg was very similar to each other while a higher ascorbic acid addition significantly affected the pasting behaviour. The pasting parameters belonging to buckwheat/ascorbic acid blends calculated using Figure 1 are shown in Table 1.

As can be seen from Table 1, the magnitude of pasting parameters (peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature) of buckwheat flour was significantly affected by the addition of ascorbic acid ($P<0.05$), depending

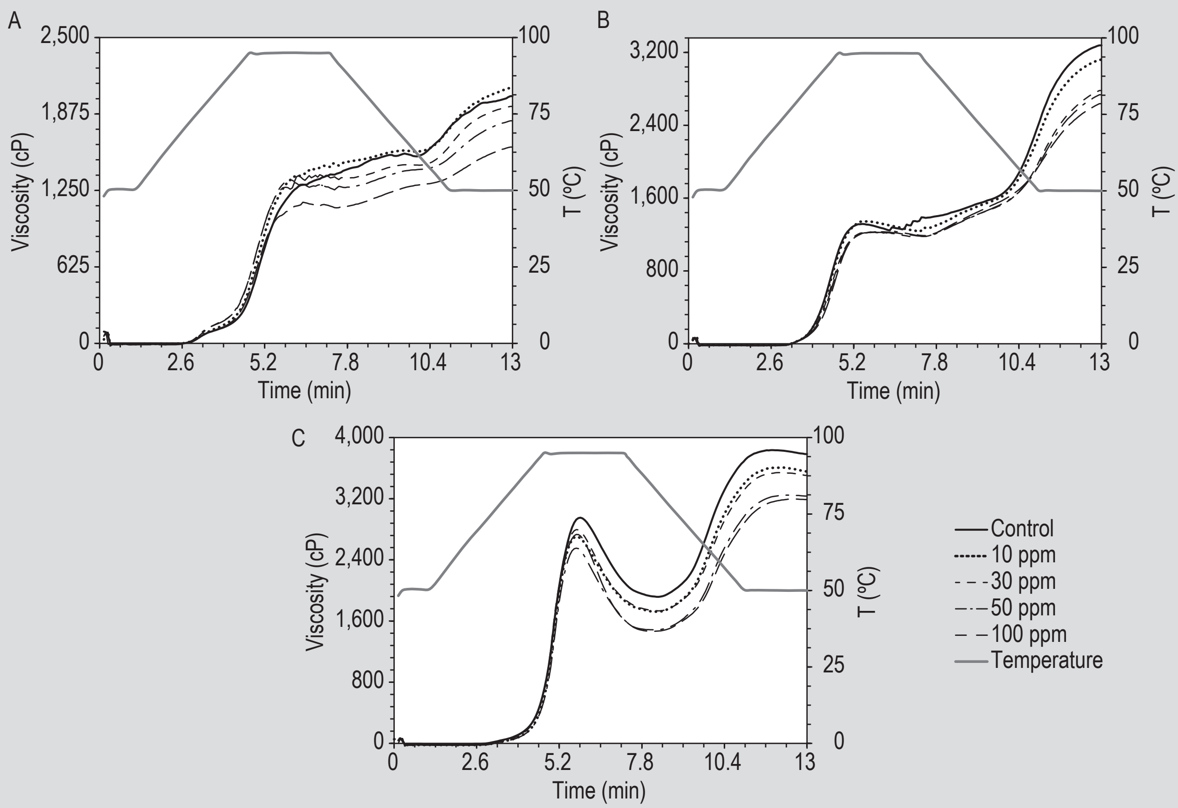

Figure 1. Effect of ascorbic acid addition at different concentrations on pasting curve of (A) buckwheat, (B) corn, and (C) rice flours.

Table 1. Effect of ascorbic acid addition on the pasting properties of buckwheat flour.[1,2]

Concentration (mg/kg)	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PeT (min)	PaT (°C)
0	1,354±26[b]	1,238±22[b]	116.0±4.4[a]	2,021±47[ab]	783±29[a]	7.00±0.00[a]	89.85±0.43[a]
10	1,451±36[a]	1,348±31[a]	102.7±9.1[b]	2,088±73[a]	740±43[a]	6.93±0.06[a]	89.31±0.49[a]
30	1,412±34[a]	1,304±34[a]	107.7±2.1[ab]	1,936±51[b]	632±17[b]	6.80±0.20[a]	80.45±7.34[b]
50	1,330±25[b]	1,253±16[b]	81.0±4.6[c]	1,819±45[c]	566±30[c]	6.44±0.30[b]	75.05±0.04[b]
100	1,154±20[c]	1,107±15[c]	53.7±0.6[d]	1,605±21[d]	498±11[d]	6.40±0.00[b]	89.30±0.47[a]

[1] Different superscript letters within a column show significant differences between the samples. Results are means ± standard deviation.
[2] PV = peak viscosity; TV = trough viscosity; BV = breakdown viscosity; FV = final viscosity; SV = setback viscosity; PeT = peak time; PaT = pasting temperature.

on the concentration level. PV, TV, BV, FV and SV values of buckwheat flour were found to be 1,354, 1,238, 116, 2,021 and 783 cP, respectively for control sample. When the ascorbic acid was added at concentration of 100 mg/kg, they decreased to 1,154, 1,107, 53.7, 1,605 and 498 cP, respectively. As PeT value changed between 6.40 and 7.00 min, PaT varied between 75.05 and 89.85 °C. When the findings were taken into consideration, it can be concluded that ascorbic acid addition markedly influenced the pasting parameters, especially at concentrations higher than 50 mg/kg.

Time versus viscosity change obtained from RVA analysis for maize flour/ascorbic acid blends is also presented in Figure 1. Similar to buckwheat flour, Figure 1 shows that the control sample and the sample including 10 mg/kg ascorbic acid had a very similar pasting behaviour. However addition of 50 and 100 mg/kg ascorbic acid significantly affected the pasting behaviour of the flour, which can be understood from viscosity differences between the samples at the same time period. The related pasting parameters calculated are presented in Table 2 for maize flour/ascorbic acid blends.

As can be seen from Table 2 PV, TV, BV, FV and SV values of the maize flour reduced to 1,238, 1,178, 39.3, 2,582 and 1,415 cP from 1,370, 1,211, 133.3, 3,278 and 2,067 cP, respectively, as ascorbic acid was added to maize flour at concentration of 100 mg/kg. PeT and PaT of the maize flour changed between 5.47-6.16 min and 81.55-83.68 °C, respectively. Similarly to buckwheat flour, the pasting parameters except for PeT and PaT were significantly affected ($P<0.05$) by ascorbic acid addition at concentrations of ≥30 mg/kg levels.

Another flour type investigated in the present study is rice flour. The effect of ascorbic acid addition on the pasting behaviour of rice flour/ascorbic acid blends is also shown in Figure 1. As it was reported for buckwheat and maize flours, being influenced of rice flour by addition of ascorbic acid was found as very similar to the other flour types. As a whole, PV, TV, FV and SV values of the rice flour decreased with increase of ascorbic acid concentration in the blend. PV, TV, FV and SV values of rice flour without addition of ascorbic acid were found to be 2,952, 1,917, 3,784 and 1,867 cP, as the addition of 100 mg/kg of ascorbic acid caused the values to decrease to 2,598, 1,410, 3,084 and 1,673 cP, respectively (Table 3).

Table 2. Effect of ascorbic acid addition on the pasting properties of maize flour.[1,2]

Concentration (mg/kg)	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PeT (min)	PaT (°C)
0	1,370±43[a]	1,211±12[a]	133.3±15.5[a]	3,278±51[a]	2,067±49[a]	6.05±0.54[ab]	81.55±0.45[c]
10	1,347±10[a]	1,228±13[ab]	119.0±12.8[a]	3,120±56[b]	1,892±63[b]	5.47±0.05[b]	82.10±0.36[b]
30	1,235±25[b]	1,163±57[b]	56.0±2.6[b]	2,782±78[c]	1,619±81[c]	5.91±0.37[ab]	82.13±0.42[b]
50	1,253±42[b]	1,167±45[ab]	47.7±3.8[b]	2,735±34[c]	1,567±55[c]	6.16±0.37[a]	82.33±0.06[b]
100	1,238±52[b]	1,178±27[ab]	39.3±3.2[b]	2,582±14[d]	1,415±30[d]	6.04±0.10[ab]	83.68±0.55[a]

[1] Different superscript letters within a column show differences between the samples. Results are means ± standard deviation.
[2] PV = peak viscosity; TV = trough viscosity; BV = breakdown viscosity; FV = final viscosity; SV = setback viscosity; PeT = peak time; PaT = pasting temperature.

Table 3. Effect of ascorbic acid addition on the pasting properties of rice flour.[1,2]

Concentration (mg/kg)	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PeT (min)	PaT (°C)
0	2,952±61[a]	1,917±108[a]	1,036±53[bc]	3,784±108[a]	1,867±17[a]	5.85±0.03[a]	86.01±0.77[b]
10	2,709±85[bc]	1,722±49[b]	987±41[c]	3,559±60[b]	1,837±34[a]	5.75±0.06[ab]	87.00±0.46[a]
30	2,796±20[b]	1,734±29[b]	1,062±10[bc]	3,506±47[b]	1,773±19[b]	5.73±0.00[b]	86.36±0.07[ab]
50	2,553±39[c]	1,484±22[c]	1,069±19[b]	3,234±37[c]	1,750±24[b]	5.73±0.00[b]	87.20±0.04[a]
100	2,598±60[c]	1,410±30[c]	1,188±53[a]	3,084±29[d]	1,673±25[c]	5.77±0.07[ab]	86.90±0.47[a]

[1] Different superscript letters within a column show differences between the samples. Results are means ± standard deviation.
[2] PV = peak viscosity; TV = trough viscosity; BV = breakdown viscosity; FV = final viscosity; SV = setback viscosity; PeT = peak time; PaT = pasting temperature.

However, no direct correlation between BV and ascorbic acid concentration was observed. BV value of the rice flour decreased from 1,036 cP to 987 cP with addition of 10 mg/kg ascorbic acid and at higher concentrations it increased to 1,188 cP (Table 3). PeT and PaT values of the samples were found to be very close to each other and they changed between 5.73 and 5.85 min and 86.01 and 87.20 °C, respectively (Table 3).

As known, ascorbic acid (AA) plays an important role as reducing agent in the Chorleywood bread process. However, AA is turned to dehydroascorbic acid (D-AA) with the oxygen and D-AA behaves as an oxidant matter in dough (Berland and Launay, 1995; Every *et al.,* 2003; Hahn and Grosch, 1998). Glutens are proteins in wheat flour and dough structure forms with activity of this protein (Shewry and Tatham, 1997; Wieser, 2007). Because gluten includes thiol (-SH) groups and they transform to disulfide (S-S) groups with oxidation (and using D-AA) and gluten structure of dough is strengthened with increasing disulfide bonds (Aamodt *et al.,* 2003). So disulfide bonds of dough increase with the addition of oxidant matter such as ascorbic acid. As a general overview, the findings of the present study highlighted that pasting parameters of the gluten-free flours, namely, buckwheat, maize and rice flours were generally influenced by ascorbic acid addition depending on its level. Ascorbic acid behaved as reductant matter in the dough and so the consistency of doughs generally decreased. Otherwise, variation of amylose/amylopectin concentrations present in flours results in the differences between viscosity of doughs prepared from them. Because the viscosity of dough decreased with the increasing of amylose level since the water-bonding capacities of dough decreased with the increase of amylose content (Bean *et al.*, 1990). Moreover, radial fissures can be formed on starch granules when heated in water due to the hydration accelerated by acid addition. This might also be a probable reason for reduction of dough viscosity (Wu *et al.*, 2010). Similar results were reported for rice flour (Wu *et al.*, 2010) and cassava starch (Wurzburg, 1995) where the effect of acids on the pasting properties of rice flour and cassava starch was investigated, respectively. Among pasting parameters, TV represents the stability of the starch granules under conditions in which heating and shearing processes are applied. According to the results, TV of the flours decreased with the addition of ascorbic acid, which led to a reduction of stability against applied shear forces and temperature changes. Therefore, the quality deficiencies in the end products could be observed due to heat applied during baking because of the addition of ascorbic acid. For this reason, ascorbic acid level should be carefully determined in order to overcome probable quality defects such as low consistency and low resistance to applied shear and temperature changes. SV is also an important pasting parameter, providing information about bread staling or starch retrogradation phenomena. During cooling of the foods including starch in the formulation, retrogradation is observed due to the association of linear amylose molecules (Kaushal *et al.*, 2012). Reduction of SV value with the addition of ascorbic acid is favourable since syneresis and staling of the bread could be retarded with ascorbic acid incorporation. Similar results were also reported by Wang *et al.* (2000) and Ohishi *et al.* (2007) for rice flour. In addition, PaT value of the control and ascorbic acid samples was found to be very close to each other. When considering the fact that PaT is one of the factors which affects the energy consumed during cooking, the findings indicated that the addition of ascorbic acid did not remarkably influence energy consumed during production process.

Effect of ascorbic acid concentration on textural properties of the flour gels

Table 4, 5 and 6 show the influence of the ascorbic acid addition on the textural properties of the gels prepared with buckwheat, maize and rice flours.

Hardness values of buckwheat, maize and rice gels were found to be 124 (Table 4), 318 (Table 5) and 240 g (Table 6), respectively. As seen, hardness value of the gels did not regularly increase or decrease with increasing ascorbic

Table 4. Effect of ascorbic acid addition at different levels on the textural properties of the buckwheat flour gel.[1,2]

Concentration (mg/kg)	Hard (g)	Adh (g×s)	Spr (mm)	Coh	Gum (g)	Chew (g×mm)	Res
0	124±10^{b}	-163±14^{ab}	0.962±0.002^{a}	0.669±0.015^{a}	83±5^{bc}	79±4^{bc}	0.034±0.002^{ab}
10	151±13^{a}	-184±21^{b}	0.953±0.006^{b}	0.609±0.013^{ab}	92±9^{ab}	88±9^{ab}	0.036±0.002^{a}
30	145±7^{a}	-181±18^{b}	0.967±0.003^{a}	0.666±0.083^{a}	97±7^{a}	93±7^{a}	0.034±0.003^{ab}
50	139±9^{ab}	-183±8^{b}	0.968±0.003^{a}	0.615±0.013^{ab}	85±4^{bc}	83±4^{bc}	0.032±0.001^{b}
100	135±6^{ab}	-153±8^{a}	0.966±0.004^{a}	0.571±0.013^{b}	77±2^{c}	75±2^{c}	0.032±0.001^{b}

[1] Different superscript letters within a column show differences between the samples. Results are means ± standard deviation.
[2] Hard = hardness; Adh = adhesiveness; Spr = springiness; Coh = cohesiveness; Gum = gumminess; Chew = chewiness; Res = resilience.

Table 5. Effect of ascorbic acid addition at different levels on the textural properties of the maize flour gel.[1,2]

Concentration (mg/kg)	Hard (g)	Adh (g×s)	Spr (mm)	Coh	Gum (g)	Chew (g×mm)	Res
0	318±31^{c}	-140±13^{a}	0.991±0.002^{a}	0.480±0.017^{a}	153±16^{b}	148±10^{b}	0.056±0.002^{c}
10	164±17^{e}	-141±13^{a}	0.994±0.007^{a}	0.421±0.015^{c}	72±6^{d}	72±8^{d}	0.064±0.007^{bc}
30	506±6^{b}	-151±8^{a}	0.991±0.002^{a}	0.437±0.002^{bc}	230±12^{a}	228±13^{a}	0.063±0.004^{bc}
50	549±27^{a}	-125±22^{a}	0.993±0.003^{a}	0.441±0.020^{bc}	242±11^{a}	240±11^{a}	0.075±0.009^{ab}
100	237±25^{d}	-135±16^{a}	0.994±0.001^{a}	0.454±0.015^{ab}	114±10^{c}	114±10^{c}	0.087±0.011^{a}

[1] Different superscript letters within a column show differences between the samples. Results are means ± standard deviation.
[2] Hard = hardness; Adh = adhesiveness; Spr = springiness; Coh = cohesiveness; Gum = gumminess; Chew = chewiness; Res = resilience.

Table 6. Effect of ascorbic acid addition at different levels on the textural properties of the rice flour gel.[1,2]

Concentration (mg/kg)	Hard (g)	Adh (g×s)	Spr (mm)	Coh	Gum (g)	Chew (g×mm)	Res
0	240±7^{a}	-139±18^{a}	0.903±0.026^{a}	0.538±0.050^{a}	123±4^{a}	117±16^{a}	0.083±0.005^{a}
10	204±12^{b}	-175±9^{b}	0.918±0.016^{a}	0.552±0.019^{a}	113±8^{ab}	104±9^{a}	0.068±0.001^{b}
30	219±19^{b}	-191±11^{b}	0.914±0.013^{a}	0.534±0.022^{a}	117±5^{ab}	107±4^{a}	0.068±0.006^{b}
50	208±7^{b}	-176±8^{b}	0.917±0.039^{a}	0.531±0.022^{a}	111±5^{b}	101±2^{a}	0.067±0.004^{b}
100	209±5^{b}	-180±10^{b}	0.942±0.036^{a}	0.531±0.007^{a}	114±4^{ab}	111±13^{a}	0.068±0.003^{b}

[1] Different superscript letters within a column show differences between the samples. Results are means ± standard deviation.
[2] Hard = hardness; Adh = adhesiveness; Spr = springiness; Coh = cohesiveness; Gum = gumminess; Chew = chewiness; Res = resilience.

acid concentration in the blend. No significant differences among ascorbic acid levels in the gels were observed in terms of hardness parameter. Regarding maize flour gels produced, hardness value decreased to 164 g as 10 mg/kg ascorbic acid was added and at higher concentrations up to 50 mg/kg it increased. Moreover, addition of more ascorbic acid reduced hardness value. Hardness of rice flour gel decreased with increasing ascorbic acid concentration added to the flour. A similar result was reported by Wu *et al.* (2010) for non-waxy rice flour, which indicated that a three-dimensional network was formed as a result of starch gelation weakened with the presence of the ascorbic acid in the matrix. Gel firmness of starches is influenced by starch retrogradation which occurs with water loss (syneresis) and crystallisation of amylopectin (Sandhu and Singh, 2007). Therefore, there may be a relation between SV and hardness of the gel. In the present study, it could be observed since we did not measure the hardness value of the gels with respect to time. When considering the fact that syneresis is observed during storage period, it could be expected that relation between SV and hardness of the gels at different storage periods can be observed.

Adhesiveness is a parameter representing the force required to remove the corresponding sample from the contact surface (Bryant *et al.*, 1995). As is also understood from definition of these parameters, adhesiveness value determines the force required for changing location of the dough from one part of the production line to another part; therefore, it also has a role in the determination of energy consumption during production. As seen from Tables 4-6, adhesiveness values of gels prepared with buckwheat flour/ascorbic acid, maize flour/ascorbic acid and rice flour/ascorbic acid blends changed between -153 and -184; -125 and -151; -139 and -191 g.s, respectively. Ascorbic acid addition influenced the adhesiveness values of the buckwheat gels differently. It increased with the addition of ascorbic acid at 50 mg/kg and adhesiveness value decreased as the more concentration was added. The adhesiveness value of maize flour gels was not significantly influenced by ascorbic acid addition. Regarding rice flour, increasing ascorbic acid concentration added led to increase in adhesiveness values of the gels.

Another TPA parameter is springiness value which is an indicator of recoverability of the sample (Huang *et al.*, 2007) after applied force is removed. Recoverability of the gels ranks among factors designating the quality of the end product, which is especially very important for bread since the freshness of the bread could be understood from springiness. For example, during transporting or storage of the bread, it is subjected to several force levels and recovering of it in short times is desired in order to maintain desired quality. Otherwise, the applied forces can adversely affect the quality of the bread. When considering the fact that deficiencies, especially in terms of viscoelastic properties of gluten-free bread, are main problems of the food industry; therefore, different food ingredients like gums are used in the gluten-free formulations to improve viscoelastic characteristics of the doughs. Springiness values of buckwheat, maize and rice gels were found to between 0.953-0.968, 0.991-0.994 and 0.903-0.942 (Tables 4-6), respectively, indicating that supplementation of ascorbic acid did not significantly affect the magnitude of springiness value (P>0.05), highlighting that ascorbic acid usage in the formulation did not have any adverse effect on the texture of bread regarding only springiness value.

Cohesiveness values of the flour/ascorbic acid blend gels are also tabulated in Table 4-6. As known, cohesiveness is attributed with the ability of the material to withstand a second deformation resulted from second compression with respect to its resistance occurred due to the first deformation. During the formation of sheet there is a need for cohesive forces, which enables cutting, shaping and moulding processes (Valderrama-Bravo *et al.*, 2015). Cohesiveness values of buckwheat, maize and rice gels were found to be 0.669, 0.480 and 0.538, respectively. For gels prepared with buckwheat and maize flours, it can be concluded that cohesiveness value decreased with ascorbic acid addition slightly depending on the concentration level. However, incorporation of ascorbic acid did not significantly affect the cohesiveness value of the rice gels (P>0.05).

Gumminess is a parameter equal to product of hardness and cohesiveness values. Gumminess values of buckwheat, maize and rice gels were determined to be 83, 153 and 123 g, respectively. As expected, considering hardness and cohesiveness values, no direct correlation between ascorbic acid concentration and gumminess value was observed. Gumminess value of buckwheat gel increased with addition of ascorbic acid up to 30 mg/kg and at higher concentrations it decreased. Change in gumminess value of the maize flour showed many fluctuations depending on ascorbic acid concentration. Gumminess value of the rice gels varied between 111 and 123 g and it can be concluded that, in general, the rice flour gumminess value was not markedly affected by ascorbic acid incorporation.

Chewiness is a textural parameter representing the energy required for masticating of the material until it is ready being swallowed (Huang *et al.*, 2007). Chewiness values of buckwheat flour/ascorbic acid, maize flour/ascorbic acid and rice flour/ascorbic acid gels were found to be between 77-96, 72-240 and 204-240 g×mm, respectively. As ascorbic acid addition significantly affected cohesiveness values of the buckwheat and maize gels (P<0.05) it did not significantly influence those of rice gels (P>0.05). Ascorbic acid concentration should be carefully adjusted in samples including buckwheat and maize flour regarding consumer group, since elderly people or some patients prefer foods which are swallowed easily with requiring minimum amount of energy.

The last textural parameter obtained from TPA analysis is resilience value indicating the recovering capability of the sample after deformation resulted from applied force (Bourne, 2002). Resilience value changed between 0.032-0.036, 0.056-0.087 and 0.067-0.083 for gels prepared with buckwheat, maize and rice flour, respectively. Ascorbic acid level did not significantly affect resilience value of buckwheat gels (P>0.05) (Table 4). Resilience value of maize gels increased with increasing ascorbic acid addition (P<0.05) (Table 5), implying that energy storing capacity of the prepared maize gels increased with increment of ascorbic acid concentration which is required for the sample to return its original shape after deformation. Therefore, ascorbic acid had a positive effect on resilience value of maize gels. However, opposite result was observed for rice gels whose resilience value decreased with increase in ascorbic acid concentration without depending on addition level.

As a conclusion for textural parameters of gluten-free gels, generally using ascorbic acid led to change in textural parameters of the gels. Textural properties of the gels are very important for quality of the products such as bread, pasta, etc., since they are subjected to different forces during transportation, storage periods; therefore their responses against those forces are very important for maintaining the desired quality. Moreover, they also determine the eating quality of the product, directly influencing consumer acceptability of the product. From these reasons, it can be concluded that the usage and concentration of ascorbic acid in gluten-free formulations should be determined also regarding textural properties since they remarkably influence the quality of the end products which could be ensuring in gluten-free products by supplementing ingredients such as hydrocolloids to improve their viscoelastic properties. The findings of the present study also indicated that response of the flour to ascorbic acid addition is different from each other, which might have resulted from the variation in chemical composition of the flours.

4. Conclusions

Improvement of the quality characteristics of gluten-free products and production of alternative gluten-free products have become the focus of interest of researchers in recent years. In order to produce such products with desired quality levels, the effects of several ingredients used in the bakery industry on the characteristics of the gluten-free products should be determined. Therefore, this study investigated the influence of ascorbic acid addition on pasting properties of the mostly being used gluten-free flours such as buckwheat, maize and rice flours and textural properties of their gels. The results of the present study indicated that ascorbic acid addition with concentration of 50 mg/kg or higher levels generally affected the pasting and textural properties, which should be taken into consideration if the ascorbic acid will be used in the formulation of the gluten-free products. Moreover, concentration of ascorbic acid should be carefully determined regarding pasting and textural properties to produce the corresponding product with desired quality.

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