

THE INFLUENCE OF PECTIN FROM APPLE AND GUM ARABIC FROM ACACIA
TREE ON THE QUALITY OF PIZZA

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Abstract

The aim of this work was to determine the effect of apple pectin and arabic gum on the organoleptic characteristics of pizza flans. Significant differences in the sensory characteristics such as flavour and change during chewing as well as the quality between the pizza flan with the addition of hydrocolloids and the pizza flan without them were found out. The additions of hydrocolloids improve the quality and flavour of pizza flans. On the other hand, higher amounts of gum arabic from acacia tree increase dryness and cause worse tenderness of the bakery product.

Keywords: dough, hydrocolloid, sensory analysis, pizza, quality

Introduction

Pizzas are known for their wide varieties and attractive appearance. New styles of pizzas are produced in the highly competitive market all the time. Although different pizzas have different visual features, general features of an acceptable pizza include a regular overall histogram; similar sub-histograms of partitioned wedges; a uniform colour of each individual topping; a similar shape of each individual topping; a pre-defined area percentage of topping objects; an even distribution of each individual topping; a smooth surface; a round contour; a proper topping overlap and an appropriate height of the pizza.^{1,2}

Additives are used in bakery products to facilitate processing, to compensate for variations in raw materials, to guarantee constant quality, and to preserve freshness and food properties.³

Hydrocolloids induce structural changes in the main components of wheat flour systems along breadmaking steps and bread storage.⁴ Such structural changes modify some enzyme selectivity⁴ and change the technological quality of doughs and breads.⁵ Hydrocolloids also affect breadmaking performance and keepability of the breads stored.^{6,7} Hydrocolloids, when they are used in small quantities (< 1% (w/w) in flour), are expected to increase water retention and loaf volume and to decrease firmness and starch retrogradation.⁴ It is known that hydrocolloids improve the bread volume encourage a, softer texture and slower staling rate.⁸ The improved properties of dough are significantly reflected in the quality parameters of fresh and stored baked products.⁴ The importance of textural and surface properties of wheat doughs lies in their effect on the dough handling ability and their predictive value.^{4,7}

Pectins are heteropolysaccharides composed of hydrocolloids that occur naturally in higher plants, and are widely used in the food industry owing to their ability to form gels, stabilize and emulsify.^{9,10} Chemically, pectins are a mixture of complex polysaccharides, homogalacturonan being the main component. This is a linear polymer made up of repeated units of alpha-(1-4)-linked D-galacturonic acid to form a long polygalacturonic chain.¹¹⁻¹³ In

their molecular structure, the carboxylic acids of galacturonic monomers may or may not be esterified with methanol, or even acetic acid, in which case the percentage of esterified groups is expressed in the degree of methoxylation (DM) and the degree of acetylation respectively.^{11,14-16} DM may reach the equivalent of 14% methoxyl, which means esterification of between 50 and 80%. These are known as highgrade methoxyl pectins, whilst those with a maximum of 7%, or a degree of esterification below 50% are regarded as low-grade methoxyl pectins.¹⁰ The extraction of pectins occurs in three main stages: the acid aqueous extraction of the extracted liquor precipitate, followed by the subsequent isolation and characterization of the pectin.^{10,17,18} During thermal processing of plant tissues, pectin is subject to depolymerization reactions, which result in texture deterioration.^{19,20} Depending on pH and degree of methoxylation (DM), β -elimination or acid hydrolysis may occur.²¹ Pectin depolymerization is one of the main causes of texture deterioration of fruits and vegetables during thermal processing.¹⁹ In case of porous plant materials, texture deterioration can be reduced by infusion of calcium ions and pectinmethylesterase.²²⁻²⁴ The latter enzyme demethoxylates pectin, giving rise to negatively charged groups which crosslink with Ca^{2+} . This interaction induces texture firming. On the other hand, demethoxylation may also influence texture by reducing the sensitivity of pectin to β -elimination while increasing the sensitivity to acid hydrolysis, in particular at elevated temperature. The influence of calcium ions on β -elimination rates have been investigated by Sila *et al.* (2006)¹⁹, Keijbets and Pilnik (1974)²⁵ and Sajjaanantakul *et al.* (1993)²⁶, while Krall and Mcfeeters (1998)²⁷ investigated the influence of Ca^{2+} on acid hydrolysis rates.

Gum arabic, also known as gum acacia, char gund, char goond or meska, is a natural gum made of hardened sap taken from two species of the acacia tree; *Acacia senegal* and *Acacia seyal*. In modern times, the most important applications of gum arabic have been not as an adhesive but as an emulsifier in the food and pharmaceutical industries. Gum arabic is

predominantly carbohydrate, which is typically 42% (w/w) galactosyl (Gal), 27% arabinosyl (Ara), 15% rhamnosyl (Rha), 14.5% glucuronosyl (GlcA), and 1.5% 4-O-methylglucuronosyl (4-O-Me-GlcA) residues in gum arabic from *Acacia senegal*; and 38% Gal, 46% Ara, 4% Rha, 6.5% GlcA, and 5.5% 4-O-Me-GlcA in gum arabic from *Acacia seyal*.²⁸ About 2% of gum arabic is protein which is characteristically rich in hydroxyprolyl, prolyl and seryl residues.²⁹⁻³¹ Various chromatographic procedures demonstrate that gum arabic is a complex mixture of macromolecules, the bulk of which fall in the range of 250–2000 kilodaltons (kDa).^{30,32-34}

The consequence of this phenomenon is a wide application of gum arabic in several foods.

It is a gummy exudation originating from the *Acacia* tree known to be produced by stress conditions, such as heat, drought and wounding.³⁵ It is also widely used for flavour encapsulation in dry mix products (e.g. puddings, desserts, cakes and soups) and in order to prevent sugar crystallisation in confectionery products.³⁵ Gum arabic is a member of the arabinogalactan–protein group^{29,36,37} and is a complex branched heteropolyelectrolyte with a backbone of 1,3-linked β -galactopyranose units and sidechains of 1,6-linked galactopyranose units terminating in a glucuronic acid or a methylglucuronic acid residue.³⁸ It is a heteropolysaccharide that contains about 2–2.4% protein covalently linked to the carbohydrate through serine and hydroxyproline residues, resulting in a mixture of arabinogalactan–protein complexes, each containing several polysaccharide units linked to a common protein core.^{35,38,39}

The aim of this study was to determine the effect of two hydrocolloids (pectin from apple, gum arabic from acacia tree) with a different chemical structure on the quality of pizza dough.

Materials and methods

Wheat flour

For the assessment, common commercial wheat flour T 530 (quantitative parameters: moisture content (MC) = 135.0 g.kg⁻¹, wet gluten content in dry matter (GC) = 341.0 g.kg⁻¹, gluten index 83, Falling number (FN) = 370 s), provided by Penam, a.s., Brno, Czech Republic, was used.

Other information about the flour was found by means of alveograph analysis (Chopin – Tripette & Renauld, France) according to the methods ISO 5530-4 (2002)⁴⁰. The information can be seen in Table 1.

Additives

The following hydrocolloids were used: Pectin from apple (Specification: synonym: Poly-D-galacturonic acid methyl ester, loss on drying < OR = 10.0%, lead < OR = 5 PPM, sugars and organic acids < OR = 20 MG, assay for methoxy groups (dry basis) > OR = 6.7%, assay for galacturonic acid (dry basis) > OR = 74.0%) from Sigma-Aldrich, Germany in the additions of 10.0 g.kg⁻¹, 15.0 g.kg⁻¹, 20.0 g.kg⁻¹ and gum arabic from acacia tree (Specification: appearance (colour)-off white, appearance (form)-powder, loss on drying ≤ 15 %) from Sigma-Aldrich, Germany in the additions of 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹.

Methods

Chemical analysis

Each sample was characterised by dry matter content and pH. Dry matter content was determined according to ISO 560116-3 (1995)⁴¹; pH of the model dough was measured three times by a pH meter (Gryf 209 S) with a glass electrode at a temperature of $22 \pm 1^\circ\text{C}$.

Baking

The doughs were prepared from 250 g of flour, 125 g.kg^{-1} of water, 5.0 g.kg^{-1} of salt, 3.0 g.kg^{-1} of yeast NOLI 42 g (*Saccharomyces cerevisia*, beige colour, crumbly mass which is moulded and formed into a cube) from Lesaffre Česko a.s., Olomouc, Czech Republic, 5.0 g.kg^{-1} of oil and corresponding amounts of the individual hydrocolloids (pectin from apple in the additions of 10.0 g.kg^{-1} , 15.0 g.kg^{-1} , 20.0 g.kg^{-1} , gum arabic from acacia tree in the additions of 12.5 g.kg^{-1} , 25.0 g.kg^{-1} and 37.5 g.kg^{-1}) were added. The doughs were handmade and then they were left to stand in a form (Bosch HEZ 317 000, Elektro-Sikora, s.r.o., Liberec) for 1 hour at a humidity of 75%. After 1 hour, the pizzas were put into an electric RedFox furnace (Tes, spol. s.r.o., Chotěboř) and they were baked for 5 minutes at a temperature of 350°C .

Sensory analysis

The pizzas were evaluated by a panel of 16 assessors (selected assessors; students of Tomas Bata University in Zlín, Faculty of Technology) trained according to ISO 8586-1 (1993)⁴² for three months. This evaluation was performed within the sensory laboratory equipped in accordance with ISO 8589 (1988)⁴³. The samples of pizzas were coded anonymously and served at room temperature ($22 \pm 2^\circ\text{C}$).

Samples: After baking, each pizza was cut into quarters. Four pieces of pizza were served on the plate. The sensory analyses were divided into two parts:

(1) One piece of pizza which was control sample of pizza (pizza without hydrocolloids) and three pieces (samples) of pizza with different amount of the individual hydrocolloids (pectin from apple in the additions of 10.0 g.kg⁻¹, 15.0 g.kg⁻¹, 20.0 g.kg⁻¹ or gum arabic from acacia tree in the additions of 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹) were put on the plate. The sensory assessors evaluated the same eight samples of pizza every day. The sensory analyses were repeated for three days. A five-point hedonic scale was used for the assessment of taste, dryness, change in taste during chewing, pliability, tenderness, absorptiveness, sensation when swallowing and quality.

(2) Four pieces (samples) of pizza were served on the plate. The best two samples of pizza with pectin from apple in the additions of 10.0 g.kg⁻¹, 15.0 g.kg⁻¹ (according to the first part (1)) were evaluated against the best two samples of pizza with gum arabic from acacia tree in the additions of 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹ (according to the first part (1)). The sensory assessors evaluated the same four samples of pizza every day. The sensory analysis was repeated for three days. A five-point hedonic scale was used for the assessment of taste, dryness, pliability, tenderness and quality.

Statistical data analysis

The results of the basic chemical analysis were statistically evaluated. The results of the sensory analysis were statistically evaluated by means of non-parametric analysis of variance (Kruskal-Wallis test), Friedman test or Wilcoxon test (Agresti, 1984)⁴⁴. The differences among the comparisons had to achieve $P < 0.05$ to show significance.

Results and discussion

Chemical analysis

The total water content in the doughs with the addition of pectin from apple and gum arabic from acacia tree was compared. This was contrasted with the standard, which was dough without these additives (control dough), in order to find out if the amount of additives influences the total water content in wheat dough. The results of the recorded values of water content are shown in Table 2.

According to the observation of the change in water content while using hydrocolloids, it can be said that the addition of hydrocolloids such as pectin from apple and gum arabic from acacia tree had no effect on the water content in the dough and thus no effect on the dry matter content (Table 2). Our results are in partial agreement with the work of (Bárcenas *et al.* 2009)⁸ who investigated that the presence of arabic gum did not affect hydration properties of the gluten.

The measured values of pH in the dough samples (Table 3) show that the control dough (made of flour, water, salt and yeast) had the lowest pH, i.e. 4.88 on average.

pH of the dough with the addition of pectin from apple was decreasing with the increasing amount of pectin from apple ($10.0 \text{ g}\cdot\text{kg}^{-1} = 5.32$; $15.0 \text{ g}\cdot\text{kg}^{-1} = 5.29$; $20.0 \text{ g}\cdot\text{kg}^{-1} = 5.27$, see Table 3). Our results are in partial agreement with the work of (Sila *et al.* 2006)¹⁹ who stated that pectin demethoxylation may also influence texture by reducing the sensitivity of pectin to β -elimination while increasing the sensitivity to acid hydrolysis, in particular at elevated temperature. Krall and Mcfeeters (1998)²⁷ investigated the influence of Ca^{2+} on acid hydrolysis rates, too.

pH of the dough with the addition of gum arabic from acacia tree was also decreasing with the increasing amount of gum arabic from acacia tree (12.5 g.kg⁻¹ = 5.47; 25.0 g.kg⁻¹ = 5.40; 37.5 g.kg⁻¹ = 5.39).

I suppose that pH in the doughs with the addition of hydrocolloids is higher in comparison with the control dough, i.e. dough without the addition of hydrocolloids, which is caused by calcium and magnesium ions contained in the pectin from apple and calcium, magnesium and potassium ions contained in the gum arabic from acacia tree. I assume that in water environment, CO₂ formed during the dough-rising period. CO₂ together with these ions creates colloid-dispersed insoluble magnesium and calcium salts which contribute to buffer capacity of the dough and thus no significant acidification of the dough occurs like in the case of the dough without the addition of hydrocolloids.

Based on the differences in the measured pH between the dough with the addition of pectin from apple and gum arabic from acacia tree, we can also take into consideration a different concentration of the cations in macromolecular structure of the additives .

Sensory analysis

Within this work, three experiments were performed.

In the first experiment, the influence of pectin from apple on the sensory characteristics of model pizza products was studied. For this purpose, three batches (batch I, II, III) of model pizza products were made. They all contained, except for the control sample, samples with the addition of pectin from apple (10.0 g.kg⁻¹, 15.0 g.kg⁻¹, 20.0 g.kg⁻¹). In these pizzas, the following characteristics were evaluated: taste, dryness, change in taste during chewing, pliability, tenderness, absorptiveness, sensation when swallowing and quality.

The second experiment was focused on the influence of gum arabic from acacia tree on the sensory characteristics of model pizza products. For this purpose, three batches (batch I, II, III) of model pizza products were made. They all contained, except for the control sample, samples with the addition of gum arabic from acacia tree (12.5 g.kg^{-1} , 25.0 g.kg^{-1} , 37.5 g.kg^{-1}). In these pizzas, the following characteristics were evaluated: taste, dryness, change in taste during chewing, pliability, tenderness, absorptiveness, sensation when swallowing and quality.

In the third experiment, two best-evaluated samples with the addition of pectin from apple (10.0 g.kg^{-1} , 15.0 g.kg^{-1}) and two best-evaluated samples with the addition of gum arabic from acacia tree (25.0 g.kg^{-1} , 37.5 g.kg^{-1}) were compared from the point of view of the highest preference among the selected assessors. In these pizzas, the following characteristics were evaluated: taste, dryness, pliability, tenderness and quality.

The results of the evaluation of the characteristics such as taste, dryness, pliability, tenderness, change in taste during chewing, the ability of the crumb to absorb saliva (saliva-absorbing capacity), sensation when swallowing and the overall evaluation (quality) are assessed by means of category quality scale of pizza samples. The results are shown in Table 4 in form of median.

Pizza batch I (with the addition of pectin from apple)

At the level of significance of 5 %, a statistically significant difference in taste was found between the control pizza sample and the samples with the addition of 10.0 g.kg^{-1} , 15.0 g.kg^{-1} and 20.0 g.kg^{-1} pectin from apple ($P < 0.05$). No statistically significant difference ($P > 0.05$) was found between the individual samples with the addition of pectin from apple. The

assessors noticed an evident improvement in taste in the sample with the additions of pectin from apple compared with the control sample (Table 4).

Furthermore, a statistically significant difference in taste during chewing was found between the control sample and the samples with the addition of 10.0 g.kg⁻¹, 15.0 g.kg⁻¹ and 20.0 g.kg⁻¹ pectin from apple ($P < 0.05$). During chewing, a change for the better was observed by the assessors in all samples with the addition of pectin from apple compared with the control sample (Table 4).

The results obtained by means of the sensory analysis reveal that a statistically significant difference in the overall evaluation (quality) was found between the control pizza samples and the samples with the addition of 10.0 g.kg⁻¹, 15.0 g.kg⁻¹ and 20.0 g.kg⁻¹ pectin from apple ($P < 0.05$). Also, the assessors noticed a better quality of the samples with the addition of pectin from apple compared with the control sample (Table 4). Our results are not in agreement with the work of (Sila *et al.* 2006)¹⁹ who investigated that pectin depolymerization is one of the main causes of texture deterioration of fruits and vegetables during thermal processing. But our results are in partial agreement with the works of (Javeri *et al.* 1991, Degraeve *et al.* 2003, Duvetter *et al.* 2005)^{24,22,23} who stated that in case of porous plant materials, texture deterioration can be reduced by infusion of calcium ions and pectinmethylesterase.

At the level of significance of 5%, no statistically significant difference ($P > 0.05$) was found in the other sensory characteristics such as dryness, pliability, tenderness, saliva-absorbing capacity and sensation when swallowing. Our results are not in agreement with the work of (Bárcenas *et al.* 2009)⁸ who investigated that hydrocolloids softer texture and slower staling rate.

Pizza batch II (with the addition of gum arabic from acacia tree)

The results obtained by means of the sensory analysis reveal that at the level of significance of 5%, a statistically significant difference in taste was found between the control pizza sample (without the addition of gum arabic from acacia tree) and the samples with the additions of 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹ gum arabic from acacia tree ($P < 0.05$). The assessors noticed an improvement in taste in the sample with the addition of 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹ gum arabic from acacia tree compared with the control sample (Table 4).

Furthermore, a statistically significant difference in dryness of the pizzas was found between the control sample and the sample with the addition of 37.5 g.kg⁻¹ gum arabic from acacia tree ($P < 0.05$). According to the assessors, the sample with the highest addition (37.5 g.kg⁻¹) gum arabic from acacia tree showed higher dryness compared with the control sample (Table 4). Our results are not in agreement with the work of (Bárceñas *et al.* 2009)⁸ who investigated that hydrocolloids softer texture.

The assessors also found a statistically significant difference in tenderness between the control pizza sample and the sample with the highest addition (37.5 g.kg⁻¹) of gum arabic from acacia tree ($P < 0.05$). The assessors noticed deterioration in tenderness and thus a harder texture in the samples with the addition of gum arabic from acacia tree (Table 4).

Also, a statistically significant difference in taste during chewing was found between the control sample and the samples with 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹ gum arabic from acacia tree ($P < 0.05$). A change for the better was observed by the assessors in all samples with the additions of gum arabic from acacia tree. No difference ($P > 0.05$) was found between the individual samples with the additions of gum arabic from acacia tree (Table 4).

At the level of significance of 5%, a statistically significant difference was found in the overall evaluation (quality) between the control sample and the samples with the additions of 12.5 g.kg⁻¹, 25.0 g.kg⁻¹ and 37.5 g.kg⁻¹ gum arabic from acacia tree (P < 0.05). An improvement in quality was observed in all samples with the addition of gum arabic from acacia tree (Table 4).

At the level of significance of 5%, no statistically significant difference (P > 0.05) was found in the other sensory characteristics such as pliability, saliva-absorbing capacity and sensation when swallowing.

Pizza batch III (the best pizza samples with pectin from apple compared to the best pizza samples with the addition of gum arabic from acacia tree)

According to the sensory analysis, at the level of significance of 5% no statistically significant difference was found between the best pizza samples with the addition of pectin from apple (10.0 g.kg⁻¹, 15.0 g.kg⁻¹) and the best pizza samples with the addition of gum arabic from acacia tree (25.0 g.kg⁻¹, 37.5 g.kg⁻¹) in any of the sensory characteristics (P > 0.05). Thus it might be claimed that the samples compared do not differ in taste, dryness, pliability, tenderness and quality (Table 4).

Conclusion

Hydrocolloids are used in the baking industry in order to improve the texture, moisture retention or overall quality of the bakery product. The aim of the work was to find out if the additives such as pectin from apple and gum arabic from acacia tree influence the organoleptic properties of pizza flans and thus their quality.

According to the results obtained from the chemical analyses regarding the comparison of the changes in pH with the increasing additions of hydrocolloids in the dough and the results of the sensory analyses, it cannot be said that the change in pH of dough caused by the addition of pectin from apple or gum arabic from acacia tree influences the organoleptic properties of pizza flans in any way. pH of the dough with the addition of hydrocolloids was decreasing with the increasing amount of hydrocolloids. But pH of control dough was the lowest.

Dry matter was treated as the main indicator of dough and its homogeneity. Another reason why dry matter was evaluated was to find out if the additions of hydrocolloids and their amounts influence the water content in dough to a large extent. The results obtained reveal that there is no relation between the amount of the hydrocolloids added and dry matter content.

The results of the sensory analysis show that the addition of pectin from apple has a positive impact on the organoleptic properties such as taste and change in taste during chewing. Also, the overall quality improves thanks to the pectin from apple added. The other organoleptic properties such as dryness, pliability, tenderness, saliva-absorbing capacity and sensation when swallowing were not affected.

The addition of gum arabic from acacia tree improves the taste of pizza flans as well as the change in taste during chewing and has a positive effect on the overall quality of pizzas. On the other hand, the highest addition of gum arabic from acacia tree had a negative effect on dryness and tenderness of the pizza samples.

There are no differences between the best pizza samples with the addition of pectin from apple (10.0 g.kg⁻¹, 15.0 g.kg⁻¹) and the best pizza samples with the addition of gum arabic from acacia tree (25.0 g.kg⁻¹, 37.5 g.kg⁻¹) in the organoleptic properties of pizza flans. These pizza flans were evaluated very well by the sensory assessors.

Thanks to their significant and positive influence on taste and the overall quality of pizzas, hydrocolloids can be recommended to the producers of pizza flans or to restaurant keepers who make these products. Moreover, it must be mentioned that the hydrocolloids added are also important from the nutritional point of view. They are an important source of fibre (pectin from apple) the consumption of which is still insufficient in the human diet. The addition of hydrocolloids thus increases the nutritional value of the final bakery product.

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Acknowledgements

This work was kindly supported by a project of the Czech Ministry of Education, Youth and Sports (Grant no. MSM 7088352101).

Table captions:

Table 1. Alveograph characteristics of investigated untreated flour

Table 2. Values of dry matter content

Table 3. Values of pH

Table 4. Results (expressed as median) of the sensory analysis of the tested pizzas with hydrocolloids from series I-III

Table 1. Alveograph characteristics of investigated untreated flour

Alveograph characteristic	Value
P*	75 mmH ₂ O
L*	134 mm
P/L*	0.56
W*	310 10E-4J
Ie	58.9%

P*: tenacity; L*: extensibility; P/L*: configuration ratio; W*: deformation energy; Ie*: elasticity

Table 2. Values of dry matter content

Hydrocolloids	Amount (g.kg ⁻¹)	Dry matter content (g.kg ⁻¹)
	10.0	422.6
Pectin from apple	15.0	419.3
	20.0	418.0
	12.5	434.3
Gum arabic from acacia tree	25.0	418.9
	37.5	427.7
Control sample	0.0	424.4

Table 3. Values of pH

Hydrocolloids	Amount (g.kg ⁻¹)	pH
	10.0	5.32
Pectin from apple	15.0	5.29
	20.0	5.27
	12.5	5.47
Gum arabic from acacia tree	25.0	5.40
	37.5	5.39
Control sample	0.0	4.88

Table 4. Results (expressed as median) of the sensory analysis of the tested pizzas with hydrocolloids from series I-III

Pizzas with hydrocolloids I-III	Amount of hydrocolloids added (g.kg ⁻¹)	Sensory evaluation (median)***							
		Taste	Dryness	Pliability	Tenderness	Change of taste in chewing	Absorptiveness	Sensation when swallowing	Quality
I (pizzas with pectin from apple)	None	5 ^a	3 ^a	3 ^a	3 ^a	4 ^a	3 ^a	3 ^a	4 ^a
	10.00	3 ^b	3 ^a	3 ^a	4 ^a	3 ^b	3 ^a	3 ^a	3 ^b
	15.00	3 ^b	3 ^a	3 ^a	3 ^a	3 ^b	3 ^a	3 ^a	2 ^b
	20.00	2 ^b	4 ^a	3 ^a	3 ^a	3 ^b	2 ^a	3 ^a	2 ^b
II (pizzas with gum arabic from acacia tree)	None	5 ^a	2 ^a	4 ^a	3 ^a	5 ^a	3 ^a	3 ^a	5 ^a
	12.50	3 ^b	3 ^{a,b}	3 ^a	4 ^{a,b}	3 ^b	3 ^a	2 ^a	3 ^b
	25.00	4 ^b	3 ^{a,b}	3 ^a	4 ^{a,b}	2 ^b	3 ^a	2 ^a	2 ^b
	37.50	3 ^b	4 ^b	2 ^a	4 ^b	3 ^b	3 ^a	2 ^a	3 ^b
III (the best pizza with hydrocolloids)	15.00 ^{p**}	3 ^a	3 ^a	4 ^a	3 ^a	-	-	-	3 ^a
	37.50 ^{ga**}	3 ^a	3 ^a	3 ^a	3 ^a	-	-	-	2 ^a
	10.00 ^{p**}	3 ^a	2 ^a	3 ^a	3 ^a	-	-	-	3 ^a
	25.00 ^{ga**}	3 ^a	3 ^a	3 ^a	3 ^a	-	-	-	2 ^a

* Hedonic scales used: Taste:1-good to 5 bad. Dryness: 1-very dry to 5 very damp. Pliability: 1-very high to 5 very low. Tenderness: 1-very tender to 5 tough. Change of taste in chewing: 1-very good to 5 very bad. Absorptiveness: 1- very high to 5 very low. Sensation when swallowing: 1-pleasant to 5 bad. Quality: 1-excellent to 5 very bad, unacceptable. Texture: 1-excellent to 5 very bad, unacceptable.

** p-pizzas with pectin from apple, ga-pizzas with gum arabic from acacia tree.

*** Median values having the same superscript letter in each column are not significantly different ($P \geq 0.05$); each group was evaluated separately