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INFLUENCE OF INULIN AND OLIGOFRUCTOSE ON THE SENSORY PROPERTIES AND ANTIOXIDANT ACTIVITY OF APPLE JELLY

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ABSTRACT
The objective of this study was to analyse the influence of inulin with different degrees of polymerization (DP values) and oligofructose preparation on the sensory properties and antioxidant activity of apple jelly. It has been determined that both the addition of inulin (independently of DP) as well as oligofructose significantly modifies colour and sensory properties and influence antioxidant activity of apple jelly. It has been observed that the manner in which water is bound by the applied preparations may have a significant impact on the analysed properties of jelly. In terms of taste, the highest scores were awarded to the desserts with addition of long-chain inulin and in terms of the overall sensory evaluation those with addition of preparation with medium length chain. The variability of the sensory properties depended on the type and level of the additive, and this impact varied between individual preparation types. The conducted study has enabled the conclusion that inulin may pose an attractive ingredient of desserts with health-promoting properties.

Keywords: apple; inulin, antioxidant; activity; sensory

INTRODUCTION
Inulin is a natural plant biopolymer that belongs to the group of long chain fructans. In plants, inulin acts as a long-term reserve material accumulates mainly in underground parts of plants or short-term in places of active growth. Inulin is stored in largest quantities in the roots and tubers of the *Asteraceae* plant (Jerusalem artichoke, dahlia, artichoke, burdock, asparagus, dandelion) and of the lily (onion, leek, garlic). In smaller amounts inulin occurs in the overground parts of the *Poaceae* plants (rye, wheat, triticale, barley). The most important source of inulin for an industrial scale are Jerusalem artichoke and chicory **(Kiełtyka-Dadasiewicz et al., 2014; Meyer et al., 2011; Nowak et al., 2012; Śliżewska et al., 2013; Trabs, Kasprick and Henle, 2011; Witczak, Jaworska and Witczak, 2020)**.

Due to the fact that inulin has very good technological properties and has an positive health-promoting effect on the human body, it is gaining more and more recognition among both food producers and consumers. Particular attention is paid to the prebiotic and dietary properties of inulin as well as its ability to improve the sensory characteristics of the product. For these reasons inulin is largely used in food production as a texture modifier, substitute of fat and sugar **(Florowska and Krygier, 2007)**.

Inulin properties depend on the source of inulin that affects polymerization degree and the nature of the bonds **(Glibowski, Kulik and Masternak, 2012; Guimarães et al., 2018)**. Physical and chemical properties of inulin (gelation and swelling ability, ability to emulsion formation, thickening, structure stabilization) are widely utilized in the food industry. In the dairy industry, it is used for the production of yoghurts and dairy desserts, in the fruit and vegetable industry for the production of juices, jams, in the fat industry for the production of margarines, in the meat industry for the production of sausages and in the confectionery industry for the production of cookies **(Delgado and Bañón, 2015; Esmaeilnejad Moghadam et al., 2019; Rodriguez Furlán and Campderrós, 2017; Keenan et al., 2014; Rodríguez-García, Sahi and Hernando, 2014; Tárrega, Torres and Costell, 2011; Witczak, Witczak and Ziobro, 2014; Ziobro et al., 2013)**. However, data on the use of inulin in dessert products are limited and they mainly concern milk-based desserts **(Esmaeilnejad Moghadam et al., 2019; Rodriguez Furlán and Campderrós, 2017; Tárrega, Torres and Costell, 2011)**.

The present study aimed at determining the influence of commercial products based on inulin at various polymerization degrees and oligofructose preparation on the antioxidant activity and sensory evaluation of apple jelly.

Scientific hypothesis

Inulin may constitute an attractive alternative for the development of fruit dessert recipes with good sensory and prebiotic properties.

MATERIAL AND METHODOLOGY

Materials

The material used in formulations for jelly preparation consisted of an apple concentrate with the extract content of 69.5% (Apkon Sp. z o.o, Przemyśl, Poland), natural apple flavor (100-fold concentrated), HPX and GR inulin preparations (Beneo, Orafti, Belgium) with different average DP, oligofructose P95 (Beneo, Orafti, Belgium), pectin (Pektowin, Poland). According to the product specification inulin GR contains additionally of a mixture of glucose, fructose and sucrose (8%), HPX 100% of inulin and the P95 preparation contains 95% oligofructose.

Sample preparation

The sample preparation was described in the work of **Witczak, Jaworska and Witczak (2020)**. In brief: the mixture of apple concentrate with water and sugar was boiled, inulin or oligofructose preparation was added, pectin was added, and the mixture was mixed, with citric acid and apple flavour being subsequently added. The solutions were poured hot into jars and were subject to pasteurization at 80 °C ±2 °C for 10 minutes. The obtained samples were cooled down and stored in refrigeration conditions (4 – 6 °C). Analyses were performed on the first day and after 6 weeks of storage. Control jelly was based on the following ingredients (per 1 kg): apple concentrate 152 g, sugar 192 g, pectin 9 g, citric acid 6 g, apple aroma 10 mL, water 631 mL. In samples 3% 30 mL of water was replaced with 30 g, and in 6% 50 mL of water with 60 g of the studied preparations.

Methods

Colour A_{420} was determined via **Burdulu and Karadeniz (2003)** method with own modification for aqueous extracts, prepared via mixing 1 g of jelly with 7 mL of distilled water. The whole mixture was stirred until the jelly dissolved in water entirely. Absorbance measurement was performed on the UV-160A spectrophotometer (Shimadzu, Japan) at 420 nm wavelength.

Total polyphenols and antioxidant activity was determined in methanol extracts. Spectrophotometry with the Folin-Ciocalteu reagent was used for the measurement of the total polyphenol content. Absorbance was measured on the UV-160A Spectrophotometer (Shimadzu, Japan) at wavelength 675 nm against 80% methanol. Polyphenols content was read from the standard curve for (+) – catechin **(Singleton, Orthofer, Lamuela-Raventós, 1999)**.

Antioxidant activity was determined with the use of free radicals 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) ($ABTS^{•+}$) according to the method proposed by **Re et al. (1999)**. Absorbance measurement was performed after 10 minutes, using the UV-160A spectrophotometer (Shimadzu, Japan) at wavelength of 734 nm. Antioxidant activity was expressed as mmol TE per 100 g d.w. (Trolox Equivalent).

Antioxidative activity was determined with the FRAP method according to the **Benzie and Strain (1996)** method. Samples were incubated with acetic buffer, $FeCl_3$ and TPTZ (2,4,6-tri(2-pyridyl)-1,3,5-triazine) solution for 10 minutes and subsequently the absorbance was measured (UV-160A spectrophotometer, SHIMADZU, Japan) at wavelength 595 nm against 80% methanol. The value of antioxidative activity was expressed in μmol Fe^{2+} per g of the edible parts of the jelly.

The sensory evaluation was performed using 5-point scale (5 = excellent, 4 = very good, 3 = good, 2 = bad, 1 = very bad). 8 persons with verified sensory sensitivity participated in the testing. Quality markers such as: surface and clarity, syneresis, colour, consistency, smell and taste. These markers corresponded to importance coefficients, respectively: 2, 2, 4, 4, 4, 4. Selection of importance coefficients was performed based on a discussion conducted within the evaluating panel prior to the evaluation.

Statistical analysis

The data were treated by one-factor analysis of variance (ANOVA), and the averages were compared with the using Duncan test at significance level 0.05. The influence of selected factors was analysed with the use of two- or three- factorial analysis of variance. Additionally the values of Pearson's correlation coefficients between selected parameters characterizing samples properties were calculated. All calculations were performed with statistical software package Statistica 12.0 (StatSoft Inc., USA).

RESULTS AND DISCUSSION

Colour characteristics

Colour measured by means of spectrometry (Table 1) after preparation exhibited the lowest value for samples with 3% P95 addition and the highest for samples with 6% addition of HPX. Samples with addition of inulin with the highest degree of polymerization at lower concentration did not differ from control sample, and at a higher concentration (6%) they were characterized by significantly higher intensity ($p = 0.035$). At the moderate degree of polymerization (GR preparation), samples at both concentrations did not differ significantly from control sample, whereas lower degree of polymerization (P95 oligofructose) resulted in reduced colour intensity with lower concentration, followed by its increase. However, in both cases the obtained values were lower than in control sample. It should be noted that according to the results of the multi-factor variance analysis, all analysed values (time, level and type of additive) had significant impact on the A420 colour. However, as it has been determined, after 6 weeks of storage, in contrast to the first day of storage, no differences could be found between the samples, yet they were also characterized by greater variability. The small variability of the A_{420} parameter obtained in this work coincides with the results obtained earlier **(Morreale, Benavent-Gil, Rosell, 2019; Witczak, Jaworska and Witczak, 2020)**.

Table 1 Color, total polyphenols and antioxidant properties of jellies.

Sample	Week	Colour A_{420} nm	Total polyphenols mg·(100 g)$^{-1}$	ABTS* (µM Trolox.g^{-1})	FRAP (µM Fe^{2+}.g^{-1})
Control	**0**	0.234 ±0.013^{bc}	16.9 ±0.4^{cd}	20.2 ±2.2^{bcd}	3.27 ±0.20
	6	0.727 ±0.006^{e}	3.43 ±0.5^{ab}	15.9 ±1.6^{a}	3.39 ±0.03
3% HPX	**0**	0.234 ±0.003^{bc}	17.1 ±1.0^{cd}	20.2 ±1.5^{bcd}	3.19 ±0.20
	6	0.734 ±0.007^{e}	4.20 ±0.4^{b}	18.6 ±1.9^{ab}	3.51 ±0.20
6% HPX	**0**	0.330 ±0.023^{d}	17.1 ±1.0^{cd}	21.1 ±1.8^{bcd}	3.01 ±0.46
	6	0.718 ±0.023^{e}	3.71 ±0.4^{b}	18.3 ±1.5^{ab}	3.44 ±0.05
3% GR	**0**	0.236 ±0.000^{bc}	15.8 ±0. 8^{c}	21.9 ±2.4^{cde}	3.48 ±0.16
	6	0.727 ±0.004^{e}	2.27 ±0.2^{a}	19.7 ±1.7^{bc}	3.24 ±0.15
6% GR	**0**	0.249 ±0.001^{c}	15.9 ±0.8^{c}	23.0 ±1.9^{de}	3.41 ±0.24
	6	0.711 ±0.007^{e}	4.75 ±0.8^{b}	19.6 ±1.2^{bc}	3.38 ±0.27
3% P95	**0**	0.188 ±0.003^{a}	17.1 ±1.0^{cd}	24.5 ±1.4^{e}	3.34 ±0.33
	6	0.711 ±0.022^{e}	3.61 ±0.6^{b}	21.0 ±0.8^{bcd}	2.95 ±0.29
6% P95	**0**	0.220 ±0.016^{b}	17.9 ±0.6^{d}	23.0 ±1.1^{de}	3.43 ±0.31
	6	0.725 ±0.001^{e}	3.76 ±1.0^{b}	18.9 ±1.0^{bc}	3.22 ±0.24
One-way ANOVA – *p*		<0.001	<0.001	<0.001	0.221
Three-way ANOVA – *p*					
Factor A (type)		<0.001	0.005	0.005	0.376
Factor B (level)		0.001	0.041	0.524	0.712
Factor C (time)		<0.001	<0.001	0.000	0.983
Factor A× Factor B		0.015	0.038	0.189	0.339
Factor A× Factor C		<0.001	0.052	0.492	0.006
Factor B× Factor C		<0.001	0.409	0.363	0.318
A× B× C		0.003	0.022	0.967	0.973

Note: Mean value of three replication ± standard deviation. Mean values signed this same letters in particular columns are non-significant different at 0.05 level of confidence.

Table 2 Sensory evaluation of jellies.

Sample	Sensory evaluation: Surface and clarity	Color	Consistency	Smell	Taste	Overall score
Control	5.0 ±0.0	5.0 ±0.1^{c}	3.9 ±0.2^{a}	5.0 ±0.0^{d}	4.4 ±0.4	4.5 ±0.5^{ab}
3% HPX	3.7 ±0.9	4.5 ±0.4^{ab}	4.7 ±0.3^{b}	4.2 ±0.5^{ab}	4.8 ±0.2	4.5 ±0.1^{a}
6% HPX	3.7 ±0.9	4.6 ±0.2^{abc}	4.4 ±0.5^{b}	3.9 ±0.1^{a}	4.6 ±0.2	4.4 ±0.1^{a}
3% GR	4.4 ±0.8	4.9 ±0.1^{bc}	4.8 ±0.3^{b}	4.7 ±0.2^{cd}	4.8 ±0.3	4.8 ±0.1^{b}
6% GR	4.4 ±0.8	4.7 ±0.5^{abc}	4.8 ±0.2^{b}	4.5 ±0.3^{bc}	4.7 ±0.2	4.7 ±0.1^{ab}
3% P95	4.4 ±0.4	4.4 ±0.4^{a}	4.4 ±0.5^{b}	4.1 ±0.2^{ab}	4.7 ±0.4	4.4 ±0.3^{a}
6% P95	4.5 ±0.4	4.5 ±0.4^{ab}	4.5 ±0.3^{b}	3.8 ±0.5^{a}	4.6 ±0.4	4.4 ±0.2^{a}
One-way ANOVA – *p*	0.055	0.041	0.007	<0.001	0.643	0.046
Two-way ANOVA – *p*						
Factor A (type)	0.034	0.036	0.122	0.000	0.699	0.005
Factor B (level)	0.895	0.972	0.617	0.024	0.312	0.217
Factor A× Factor B	0.982	0.535	0.539	0.957	0.971	0.844

Note: Mean value of five replication ± standard deviation. Mean values signed this same letters in particular columns are non-significant different at 0.05 level of confidence.

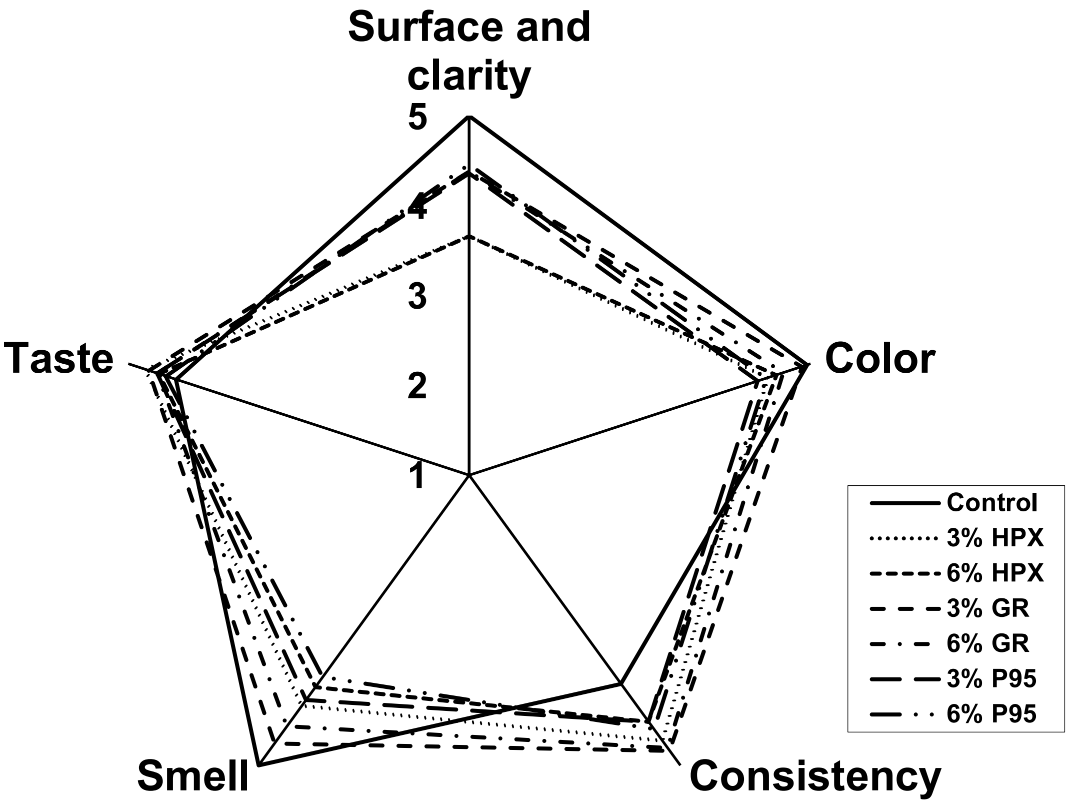

Figure 1 Sensory evaluation of jellies.

Morreale, Benavent-Gil and Rosell (2019) did not find a direct impact of DP on the values characterizing the color of gluten-free bread, but the authors found variability due to yeast type and inulin producer. In turn, **Witczak, Jaworska and Witczak (2020)** found the variability of the L* parameter responsible for the color lightness depending on the type and amount of inulin added. The analysis of the cited works and the results obtained in this work allows us to state that the change in color is conditioned by inulin interactions with the other components of the system, and the variability is not directly related to inulin DP.

Polyphenol content

On the first day of storage only samples with the addition of GR preparation were characterized by lowered content of total polyphenols (Table 1) relative to the control sample, however, also in this case statistically significant differences could not be found. Slightly larger reduction (ca. 10%) in polyphenol content in orange jellie was found after adding trehalose **(Kopjar et al., 2016)**. In turn, **Cano-Lamadrid et al. (2020)** found significant changes in polyphenol content depending on the composition of jelly candies based on pomegranate juice. The authors **(Cano-Lamadrid et al., 2020)** found a decrease in the content of polyphenols with an increase in the addition of gelatin and an increase with the replacement of sugar with honey.

Similarly as after preparation, following the six week storage period, no significant differentiation relative to control sample could be determined. However, in the stored samples, a clearly differentiated impact of individual preparations and concentration levels can be seen. However, a statistically significant change with increased concentration was determined only in the case of the GR preparation ($p = 0.006$). Similar effect of limiting the decline in polyphenol content during storage was found for orange jellie with the addition of trehalose, what according to the authors is due to the protective effect of the additives used **(Kopjar et al., 2016)**.

Antioxidant activity

An increase of antioxidant activity determined via ABTS method was found (Table 1). The preparation with the longest chain produced a minor increase, while the oligofructose preparation P95 changed the value of ABTS activity to the largest extent. However, statistically significant differences relative to control sample were determined only in the case of 3% addition of this preparation. Similar increase in antioxidant activity determined via ABTS method was found after introducing trehalose into orange jelly and depending on the addition of gelatin for jelly candies based on pomegranate juice **(Cano-Lamadrid et al., 2020; Kopjar et al., 2016)**. After the six week storage period, the samples with addition of GR and P95 preparations were characterized by significantly higher values of ABTS activity than control sample. Samples with addition of the HPX preparation did not differ statistically, although also in this case the values were higher than in control sample. Similar relationship after storage was obtained for the addition of trehalose to orange jelly **(Kopjar et al., 2016)**. According to **Kopjar et al. (2016)** the change in antioxidant activity may be caused by the degradation of the present antioxidants or their chemical modification.

No statistically significant differentiation of activity determined via FRAP method could be found (Table 1). However, also in this case certain trends can be observed. After preparation, lower values were recorded for samples with HPX addition, in the two remaining cases the values were higher than for control sample. These values differed slightly after storage, where the lowest FRAP activity value was determined for samples with P95 addition. The difference of the behavior of the antioxidant activity depending on the method is due to the fact that each method is specific to only one antioxidant mechanism **(Cano-Lamadrid et al., 2020)**.

Sensory evaluation

Figure 1 and Table 2 presents results of sensory evaluation of the tested jellies. In the case of surface and clarity, no statistically significant difference in one-factor variance analysis could be found. However, a two-factor variance analysis indicated a significant impact of the additive type. This is further indicated by the evaluation results. Control sample was awarded the highest scores, while the lowest to the sample with HPX addition at both levels. The two remaining preparations produced jellies with a similar evaluations, yet significantly lower than control. No differentiation was observed between samples in the case of syneresis (data unpublished). The analysed samples differed significantly in terms of colour (at the level of 0.05). Similarly to surface and clarity, the highest score was awarded to control sample. Similar scores were awarded to the sample with addition of 3% GR, and only slightly lower scores were awarded to samples with 6% addition of HPX and GR preparations – in these cases the differences were statistically insignificant relative to control sample. Worse scores were obtained for the remaining cases. Two-factor variance analysis demonstrated statistically significant impact of the type of preparation used, yet no impact of the addition level. According to the results of one-factor analysis of variance results, the samples differed significantly in terms of consistency and in this case the control sample was awarded the lowest scores. The highest scores were awarded to samples with GR addition (at both levels) and 3% HPX. Slightly lower scores, yet still better than for control sample, were awarded to samples with addition of P95 and 6% HPX. However, it should be noted that according to the results of statistical analyses, no significant differentiation between samples with addition of preparations occurred and only control sample differed significantly from the remaining samples. The greatest differentiation was obtained in the case of smell. In this case, statistical analysis indicates a significant impact of both type and level of additive. The highest score was awarded to control sample and value of the score decreased with the increase of addition level, independently of preparation type. Although samples with P95 addition were awarded the lowest scores, this evaluation was very close to the scores obtained for HPX (statistically insignificant differences). No statistically significant differences were obtained for taste evaluation. However, analysis of the results shows that control sample was awarded the lowest score. The remaining samples were assessed at a very similar level, and the best scores were awarded to samples with addition of 3% inulin products (HPX and GR). The overall evaluation enables the statement that the GR granulated inulin preparation has been evaluated most favourably among the analysed products. The two remaining products obtained overall evaluations at a similar level as control sample. It should be also noted that evaluations for different concentrations were identical or remained at a very similar level. This indicates that a suitably selected recipe stemming from the balance between the amount of preparation and water enables obtaining samples with highly similar sensory traits. Moreover, overall evaluation demonstrates the possibility of utilising all tested preparations as ingredients of jellies based on apple concentrate. These results comply with the results obtained for other products. Values comparable with control in terms of taste, smell and consistency were obtained for kefir with addition of inulin **(Glibowski and Kowalska, 2012)**. On the other hand, **Gramza-Michałowska and Górecka (2009)** obtained increased scores for point evaluations of products with addition of inulin – sponge cake, cake cream, natural yoghurt and ground pork burgers. The study of **Brennan and Tudorica (2008)** analysed the impact of the level and type of dietary fibre on yoghurt properties. No significant differentiation of the overall sensory evaluation was found, although the highest overall evaluation score was awarded to samples with 6% addition of inulin and 6% skimmed milk powder.

CONCLUSION

The obtained results have enabled the statement that addition of inulin and oligofructose significantly modifies the properties of apple jellies. Colour parameter A420 (corresponding to the colour lightness) were subject to a considerable variability. Sensory analysis has demonstrated strong impact of additives only on the smell characteristics. Despite the fact that significant differences have been shown, the variability of the remaining parameters of sensory characteristics was not high. It should be underlined that the highest scores in terms of taste were obtained for the jelly supplemented with HPX preparation, and in terms of overall evaluation with the samples with the addition of GR preparation. A significant impact of additives was observed on the total polyphenols content and antioxidant activity determined via the ABTS method. However, no variability could be found for activity determined via FRAP method. The conducted analyses provide an indication that inulin may constitute an attractive alternative for the development of fruit dessert recipes, which would enable obtaining products with prebiotic properties.

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