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THE INFLUENCE OF STORAGE CONDITIONS ON TEXTURE PARAMETERS AND SENSORY QUALITY OF SOUR CHERRY JAMS WITH VARIOUS PLANT ADDITIVES

S u m m a r y

The objective of the research study was to compare the texture and colour parameters as well as and some sensory indicators of low-sugar sour cherry jams with and without pro-health plant ingredients (the latter jams constituted a control sample). The sour cherry jams studied contained chokeberry, elderberry, Japanese quince, flax seeds, wheat germs and inulin; their content was 6 ÷ 42 % by weight of the total sour cherry fruit. Steviol glycoside was added to replace some part of sucrose and to reduce its amount by 15 ÷ 48 %. The products obtained were analysed immediately after production and, next, 6 and 12 months after storing them at a refrigeration (10 ºC) and room temperature (20 ºC). In the jams the dominant colours were red (a*) and yellow (b*). The brightest jams were those with added Japanese quince, flax seeds and wheat germs. Chokeberry and elderberry added caused the jams to significantly darken. After storage changes were found in the texture and colour parameters, though those in the jams stored at 10 ºC were smaller. The jams underwent a sensory evaluation: high scores (4.6 ÷ 5.0 points) were awarded to the jams immediately after production and after a period of their 6 month storage. Also after a 12 month storage period, the quality of jams was awarded high scores (4.7 ÷ 5.0 points) except for the jams with flax seeds and wheat germs that were lower scored (3.8 ÷ 4.0 points). The analysis of the jam samples studied show that storing the jams at a lower temperature is more beneficial and the storage duration of jams with flax seeds and wheat germs should be reduced to 6 months. The conclusion is that the jams with the selected plant component added (chokeberry, elderberry, Japanese quince, flax seeds, wheat germs and inulin) can be a beneficial alternative to traditional jams.

Key words: sour cherry, jam, plant additives, texture, colour, sensory properties

Introduction

Of the fruit products with extended shelf life, jams are the most popular. In the traditionally produced jams, sugar comprises the bulk of the product and constitutes

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more than 40 % of its total weight, which is important for physical, chemical and microbiological properties thereof [1]. However sugar increases the calorific value of product and it is not recommended for diabetics. Thus, in order to meet consumer preferences, manufacturers have boosted their production of jams with alternative sweeteners such as xylitol, sorbitol, aspartame or steviol glycoside to completely or partially replace sucrose. The product with sucrose substitutes should have the same texture parameters and taste as the traditional product [2].

In addition to reducing the calorific value of jams, it is also preferable to increase their nutritional value, i.e. the content of bioactive compounds or dietary fibre. This can be achieved when applying fruit with high nutritional value. These are for example fruits of black chokeberry, elderberry or Japanese quince which, simultaneously, impart sensory properties to the product. Flax seeds and wheat germs are also interesting additives. Owing to their high content of fibre, they can have an effect on the texture of the product. In addition inulin, a natural prebiotic, also exhibits textural properties [3].

Sour cherry (*Prunus cerasus* L.) is an attractive fruit owing to its taste, nutritional value and the fact that it is a good source of natural antioxidants [4, 5]. Polyphenols occurring in cherries, including anthocyanins, have pro-health effects and they are also responsible for the colour of the product.

Storage conditions can cause changes in the physical and chemical properties of constituents of the product which, in turn, affect general properties thereof such as colour, taste or consistency [6, 7]. For the consumer those features are important when choosing a product. Firstly consumers evaluate appearance and colour and then taste, smell and texture [8].

The objective of the research study was to assess the effect of plant materials (black chokeberry, elderberry, Japanese quince, flax seeds, wheat germs and inulin) added and storage conditions on the texture, colour and sensory attributes of low-sugar sour cherry jams. The jams were evaluated immediately after manufacture and then after 6 and 12 months of storage at a refrigeration temperature (10 ºC) and at a room temperature (20 ºC).

Materials and methods

Materials

The material studied consisted of low-sugar jams produced from the 'Łutówka' cv. of sour cherry (control sample) and of jams containing enriching ingredients such as black chokeberry, elderberry, Japanese quince, flax seeds, wheat germs and inulin.

The jams were produced from frozen fruits prepared from fully ripened fresh fruit. The fruit was sorted and washed immediately after harvest and its inedible parts were rejected. Sour cherries were frozen whole while chokeberries, elderberries and

Japanese quinces were homogenized prior to freezing. Flax was added in the form of ground flax seeds defatted (Oleofarm, Wrocław, Poland). Wheat germs were obtained from wheat grain; it was purchased directly from the producer (Sante, Warsaw, Poland). Inulin preparation Orafti® GR (BENEO GmbH, Mannheim, Germany) with a DP ≥ 10 degree of polymerization was also added to the jams.

Sucrose, steviol glycoside (Bio Nature24, Goerlitz, Germany) as a partial sucrose replacement, citrus-apple pectin (NECJ-A2, Naturex, Avignon, France) and citric acid (Chem Point, Kraków, Poland) were also applied to manufacture jams. Steviol glycoside was added in the proportion of 0.2 g/kg of the product to partially replace sucrose and, thus, to reduce a calorific value of the jams.

Preparation of jams

The following variants of sour-cherry jams were made: SC0 – without plant ingredients and sweetened only with sucrose (control sample), SCS – without plant ingredients and sweetened with sucrose and steviol glycoside, SCCh – with black chokeberry (15 %), SCE – with elderberry (15 %), SCJ – with Japanese quince (8 %), SCF – with flax seeds (3 %), SCWG – with wheat germs (3 %), SCI – with inulin (10 %). The jam recipes were developed based on the preliminary technological analyses performed in order to determine optimal amounts of individual plant ingredients.

All the jams with pro-health ingredients were sweetened with sucrose and steviol glycoside. Fruits and sweeteners were weighed according to the jam formulation shown in Table 1. The fruit comprised 50 % of the mass of the final product. A final extract was about 30 % and the total acidity was set at 1 %.

Table 1. Composition of sour cherry jams [g/kg]
Tabela 1. Skład dżemów wiśniowych [g/kg]

Sample Próba	Ingredients / Składniki											
	SC	Ch	E	J	F	WG	I	Sucrose Sacharoza	Steviol glycoside Glikozydy stewiolowe	Pectin Pektyna	Citric acid Kwas cytrynowy	Water Woda
SC0	500							268	0.0	11.2	4.0	216.8
SCS	500							220	0.2	11.2	4.0	264.4
SCCh	350	150						224	0.2	11.2	4.0	260.6
SCE	350		150					226	0.2	11.2	3.6	259.0
SCJ	420			80				228	0.2	11.2	1.6	259.0
SCF	500				30			212	0.2	16.0	4.0	233.8
SCWG	500					30		212	0.2	16.0	4.0	233.8
SCI	500						100	140	0.2	11.2	4.0	244.6

Composition / Skład: SC – sour cherry / wiśnia; Ch – black chokeberry / aronia; E – elderberry / czarny bez; J – Japanese quince / pigwowiec japoński; F – flax seeds / nasiona lnu; WG – wheat germs / zarodki pszenne; I – inulin / inulina.

Sample / Próba: SC0 – sour cherry jam without plant ingredients and sweetened with sucrose / dżem wiśniowy bez dodatków roślinnych słodzony sacharozą; SCS – sour cherry jam without plant ingredients and sweetened with sucrose and steviol glycoside / dżem wiśniowy bez dodatków słodzony sacharozą i glikozydem stewiolowym; SCCh – sour cherry jam with 15 % of chokeberry added / dżem wiśniowy z 15-procentowym dodatkiem aronii; SCE – sour cherry jam with 15 % of elderberry added / dżem wiśniowy z 15-procentowym dodatkiem czarnego bzu; SCJ – sour cherry jam with 8 % of Japanese quince added / dżem wiśniowy z 8-procentowym dodatkiem pigwowca japońskiego; SCF – sour cherry jam with 3 % of flax seeds added / dżem wiśniowy z 3-procentowym dodatkiem nasion lnu; SCWG – sour cherry jam with 3 % of wheat germs added / dżem wiśniowy z 3-procentowym dodatkiem zarodków pszennych; SCI – sour cherry jam with 10 % of inulin added / dżem wiśniowy z 10-procentowym dodatkiem inuliny.

The fruits were boiled together with sweeteners and water in an open pan (for 20 min at 103 ºC). Afterwards a previously prepared 4 % (w/v) solution of the gelling agent (citrus-apple pectin NECJ-A2) was homogenized and added to fruits. The whole batch was mixed and cooked again for several minutes. Finally citric acid was added and mixed. Next the jams were bottled in 0.2 l glass jars, pasteurized at 82 ÷ 85 ºC for 15 min and finally cooled to 20 ± 2 ºC. The jams were stored at a refrigeration temperature (10 ºC) and a room temperature (20 ºC) until evaluation. Their evaluation was conducted immediately after production and after 6 and 12 months of storage. For analysis no less than 4 portions (jars) of each jam were used.

Texture analysis

Jam texture was analyzed according to the procedure as described by Genovese *et al.* [9] using a TA-XT2 plus texturometer (Stable Micro Systems Ltd., Surrey, England). The compressing rate was 2 mm/sec; the P/20 probe (20 mm in diameter) moved to a penetration depth of 20 mm; the trigger force was 1 g. The following texture parameters were established as texture indicators of the examined jams: F_e (N) – gel strength, FR (N) – rupture force, E (Ns) – energy of penetration, A (Ns) – adhesiveness. Based on the F_e, FR and E parameters it is possible to draw conclusions about the hardness of gel, while the A parameter indicates its tendency to adhere to different surfaces. The results obtained were calculated using a Texture Exponent software (Stable Micro Systems Ltd., Surrey, England).

Instrumental colour analysis

The colour of the upper surface was measured with the use of Konica Minolta CM-3500d equipment (Konica Minolta Inc., Tokyo, Japan) with reference to a D65 illuminant and a visual angle of 10º. The results were expressed using a CIE (L*a*b*) system. On the basis of the measurement performed, the following parameters were set: L* – lightness (L* = 0 blackness, L* = 100 whiteness), a* – the proportion of green (a* < 0) or red (a* > 0), b* – the proportion of blue (b* < 0) or yellow (b* > 0), C* – chroma and hº – hue angle. Every sample was analyzed in five replications. The colour differences (ΔE*) between the samples were calculated according to the equation: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

Sensory evaluation

Sensory evaluation was carried out using a scoring method with a 5-score scale, with 1 as the lowest and 5 as the highest grade. With respect to the sensory sensitivity, a 15-person panel met the requirements of ISO 3972:2011 [10]. For the individual quality factors, the following significance factors were employed: external appearance of the product, i.e.: surface (syneresis) – 2, structure (disposition of fruit parts in the content of jam) – 3, colour – 4, consistency – 3, aroma (type and desirability) – 4, taste (type and desirability) – 4. The significance factors were determined on the basis of the opinion of panellists, their experience in sensory evaluation and profound acquaintance with this type of product was approved.

Statistical analysis

The measurement results of texture and colour parameters were statistically analyzed using a two-factor analysis of variance (first factor – type of jam, second factor – storage), while those concerning the sensory analysis were subjected to one-factor analysis based on Snedecor F and Student's t tests. The least significant difference (LSD) was calculated at a probability level of $p < 0.05$. A Statistica 12.0 (StatSoft, Tulsa, USA) program was applied.

Results and discussion

Texture parameters of sour cherry jams

Texture is an important parameter for sensory acceptance and it depends on the composition of raw materials. Jam is a viscoelastic food material which exhibits both the requirement of mechanical stability when being stored and handled and the requirement of instability when spread over bread [2]. So when a new product is developed, it is beneficial to combine sensory evaluation with the measurement of texture parameters. Depending on the plant ingredients used, the gels in the jams examined were characterized by average gel strengths of 1.02 ÷ 3.01 N and the rupture force ranged between 1.30 and 4.79 N (Tab. 2).

The hardness of the jams coded as SC0, SCS, SCJ and SCI was comparable. The jams with wheat germs and flax seeds added were the hardest; their F_e value was higher compared to the SC0 jam, 87 % and 166 % on average, respectively. This could be owing to the high content of protein and fibre, since protein can bind twice as much fluid in relation to its weight and 3 - 19 times more fibre [11]. Wheat bran contains 33 ÷ 63 % of fibre and 10 ÷ 19 % of protein, while wheat germs have slight amounts of

Table 2. Values of gel strength (F_e), rupture force (FR), energy of penetration (E) and adhesiveness (A) of sour cherry jams

Tabela 2. Wartości mocy żelu (F_e), siły rozrywającej (FR), energii penetracji (E) i adhezyjności (A) dżemów wiśniowych

Parameter Parametr	Sample Próba	Storage time at 10 °C and 20 °C [months] Czas składowania w temp. 10 i 20 °C [miesiące]					$\bar{x}$
		0	6 temp. 10 °C	6 temp. 20 °C	12 temp. 10 °C	12 temp. 20 °C	
F_e [N]	SC0	0.67 ± 0.03	0.81 ± 0.10	0.99 ± 0.07	1.72 ± 0.06	1.45 ± 0.11	1.13
	SCS	0.60 ± 0.05	0.76 ± 0.02	0.86 ± 0.09	1.63 ± 0.04	1.55 ± 0.10	1.08
	SCCh	1.35 ± 0.15	1.42 ± 0.24	1.31 ± 0.13	1.52 ± 0.04	1.43 ± 0.05	1.41
	SCE	0.96 ± 0.15	1.40 ± 0.22	1.34 ± 0.14	2.11 ± 0.15	1.59 ± 0.13	1.48
	SCJ	0.97 ± 0.19	0.91 ± 0.08	0.79 ± 0.12	1.33 ± 0.14	2.06 ± 0.17	1.21
	SCF	2.67 ± 0.18	2.88 ± 0.16	2.94 ± 0.22	3.64 ± 0.17	2.94 ± 0.16	3.01
	SCWG	1.75 ± 0.15	1.82 ± 0.11	2.06 ± 0.07	2.52 ± 0.17	2.38 ± 0.20	2.11
	SCI	0.58 ± 0.06	0.82 ± 0.03	0.64 ± 0.09	1.68 ± 0.18	1.35 ± 0.12	1.02
	$\bar{x}$	1.19	1.35	1.37	2.02	1.86	
	LSD $p < 0.05$	I – 0.116, II – 0.092, I × II – 0.259					
FR [N]	SC0	1.22 ± 0.09	1.23 ± 0.11	1.21 ± 0.14	3.39 ± 0.17	3.03 ± 0.18	2.02
	SCS	0.95 ± 0.13	1.16 ± 0.15	1.08 ± 0.11	2.40 ± 0.21	2.47 ± 0.11	1.61
	SCCh	2.01 ± 0.14	2.40 ± 0.14	2.60 ± 0.11	2.12 ± 0.10	2.72 ± 0.10	2.37
	SCE	1.27 ± 0.03	1.66 ± 0.19	1.57 ± 0.17	2.63 ± 0.11	1.95 ± 0.19	1.82
	SCJ	1.18 ± 0.05	1.36 ± 0.17	1.31 ± 0.13	2.53 ± 0.13	2.77 ± 0.16	1.83
	SCF	3.47 ± 0.09	4.55 ± 1.10	3.54 ± 0.17	6.08 ± 0.01	6.29 ± 0.14	4.79
	SCWG	2.23 ± 0.11	2.42 ± 0.18	2.58 ± 0.10	5.30 ± 0.17	5.69 ± 0.18	3.64
	SCI	0.82 ± 0.01	1.32 ± 0.13	0.79 ± 0.07	1.74 ± 0.12	1.81 ± 0.24	1.30
	$\bar{x}$	1.64	2.01	1.84	3.27	3.34	
	LSD $p < 0.05$	I – 0.191, II – 0.151, I × II – 0.427					
E [Ns]	SC0	9.92 ± 0.75	11.48 ± 0.64	13.46 ± 1.46	24.22 ± 2.64	24.67 ± 1.38	16.75
	SCS	7.02 ± 1.57	10.22 ± 0.61	12.75 ± 1.56	21.04 ± 0.91	19.58 ± 2.54	14.12
	SCCh	18.18 ± 1.77	21.44 ± 1.78	23.13 ± 1.83	24.91 ± 2.72	21.87 ± 0.57	21.91
	SCE	12.71 ± 1.47	17.98 ± 1.20	19.98 ± 0.78	22.38 ± 1.59	35.22 ± 1.72	21.65
	SCJ	12.28 ± 0.59	11.84 ± 0.82	12.49 ± 1.21	23.73 ± 2.82	32.60 ± 0.78	18.59
	SCF	31.80 ± 1.83	44.98 ± 2.04	33.53 ± 2.19	50.63 ± 2.66	48.07 ± 1.85	41.80
	SCWG	19.79 ± 1.30	23.87 ± 0.72	26.00 ± 1.63	39.08 ± 2.61	34.33 ± 2.23	28.61
	SCI	6.45 ± 0.52	10.79 ± 1.35	12.47 ± 2.01	12.48 ± 2.12	20.57 ± 0.63	12.55
	$\bar{x}$	14.77	19.08	19.23	27.31	29.61	
	LSD $p < 0.05$	I – 1.393, II – 1.101, I × II – 3.114					
A [Ns]	SC0	-0.31 ± 0.06	-0.31 ± 0.03	-0.31 ± 0.03	-0.90 ± 0.14	-1.15 ± 0.28	-0.67
	SCS	-0.28 ± 0.07	-0.25 ± 0.02	-0.25 ± 0.06	-0.84 ± 0.05	-0.91 ± 0.05	-0.56
	SCCh	-0.45 ± 0.01	-0.48 ± 0.07	-0.56 ± 0.06	-0.53 ± 0.04	-0.67 ± 0.08	-0.56
	SCE	-0.30 ± 0.04	-0.31 ± 0.05	-0.35 ± 0.04	-0.64 ± 0.08	-0.73 ± 0.20	-0.51
	SCJ	-0.36 ± 0.07	-0.36 ± 0.03	-0.38 ± 0.06	-1.16 ± 0.08	-1.23 ± 0.10	-0.78
	SCF	-0.98 ± 0.10	-1.75 ± 0.17	-1.30 ± 0.09	-1.55 ± 0.11	-1.32 ± 0.13	-1.48
	SCWG	-0.57 ± 0.04	-0.66 ± 0.06	-0.67 ± 0.01	-1.39 ± 0.11	-1.48 ± 0.11	-1.05
	SCI	-0.17 ± 0.04	-0.18 ± 0.01	-0.21 ± 0.01	-0.67 ± 0.08	-0.75 ± 0.09	-0.45
	$\bar{x}$	-0.43	-0.54	-0.50	-0.96	-1.03	
	LSD $p < 0.05$	I – 0.067, II – 0.053, I × II – 0.149					

Explanatory notes / Objaśnienia:
Meanings of symbols as in Tab. 1. / Objaśnienia symboli jak w tab. 1.; Table shows mean values ($\bar{x}$) ± standard deviations / W tabeli przedstawiono wartości średnie ($\bar{x}$) ± odchylenia standardowe; n = 5; LSD p < 0.05 for type of jams (I) / LSD p < 0,05 dla rodzaju dżemu (I); storage (II) / przechowywanie (II); interaction (I × II) / interakcja (I × II); n.s. – insignificant / nieistotne.

fibre, but about 27 % of protein [12]. The FR and E values in those jams were also the highest. Also, by adding black chokeberries and elderberries, the strength of the gel (F_e) increased by 25 % and 31 %, while the energy of penetration (E) by 31 % and 29 %, respectively. Adhesiveness (A) is an important food quality parameter. In the cherry jams examined, the level of A parameter was the highest in the hardest jams, i.e. with wheat germs (-1.05 Ns) and flax seeds (-1.48 Ns).

Storing the jams examined caused the value of the evaluated texture parameters to increase; the jams stored for one year at 10 ºC were harder than those kept at 20 ºC (Tab. 2). The increase in the hardness of jams during their storage confirms the findings of other authors [13].

Based on the obtained results it was found that the sour-cherry jams with chokeberry added and stored for 12 months at a refrigeration temperature showed the lowest changes in the value of F_e, FR, E and A parameters (the changes ranged between 5 and 37 %) compared to the non-stored jam samples. However the jams with the chokeberries added and stored at a room temperature for a period of 12 months were characterized by the smallest changes in F_e (6 %) and E (20 %) only. Next the jams containing wheat germs showed the lowest changes in FR (7 %) compared to the value obtained immediately after production. The 12-month stored jams with flax seeds were characterised by the smallest change in A (35 %) compared to the non-stored samples.

Colour parameters of sour cherry jams

Consumer choice is chiefly determined by colour, thus it is an indicator which may also have an effect on product acceptability [8]. Colour deterioration is primarily attributed to decomposition of anthocyanins during jam manufacturing and the formation of greyish brown compounds such as Maillard reaction products [14].

The mean lightness (L*) value of the control jam sample sweetened only with sucrose (SC0) was 7.02 (Tab. 3). Jams with steviol glycoside, Japanese quince, wheat germs and flax seeds were significantly lighter. In turn the addition of dark-coloured fruits (black chokeberry, elderberry) significantly affected the darkening of jams. Throughout the storage period of jams the L* values were changing and the samples stored at 10 ºC were generally darker than those kept at 20 ºC. According to Melgarejo et al. [15], a temperature of 5 ºC provides the optimum storage conditions for jams.

Table 3. Values of colour parameters (L*a*b*) of sour cherry jams
Tabela 3. Wartości parametrów barwy (L*a*b*) dżemów wiśniowych

Parameter Parametr	Sample Próba	Storage time at 10 °C and 20 °C [months] Czas składowania w temp. 10 i 20 °C [miesiące]					$\bar{x}$
		0	6 temp. 10 °C	6 temp. 20 °C	12 temp. 10 °C	12 temp. 20 °C	
L*	SC0	6.04 ± 0.38	5.30 ± 0.22	7.54 ± 0.24	8.41 ± 0.41	7.82 ± 0.44	7.02
	SCS	7.59 ± 0.57	8.38 ± 0.41	7.90 ± 0.53	9.39 ± 0.41	8.57 ± 0.30	8.37
	SCCh	5.72 ± 0.59	5.10 ± 0.38	5.43 ± 0.27	4.62 ± 0.23	5.44 ± 0.25	5.26
	SCE	5.58 ± 0.66	5.21 ± 0.33	6.47 ± 0.78	5.04 ± 0.26	6.55 ± 0.89	5.77
	SCJ	13.13 ± 0.57	8.97 ± 0.41	10.88 ± 0.59	10.93 ± 0.52	9.13 ± 0.48	10.61
	SCF	18.41 ± 0.54	17.71 ± 0.86	17.54 ± 0.41	17.24 ± 0.32	17.92 ± 0.39	17.76
	SCWG	17.03 ± 0.67	15.65 ± 0.51	15.24 ± 0.70	15.55 ± 0.32	16.25 ± 0.39	15.94
	SCI	7.04 ± 0.38	5.93 ± 0.48	6.14 ± 0.45	5.60 ± 0.11	8.59 ± 0.49	6.66
	$\bar{x}$	10.06	9.03	9.64	9.60	10.03	
	LSD p < 0.05	I – 0.464, II – 0.367, I × II – 1.037					
a*	SC0	16.63 ± 0.44	17.76 ± 0.54	16.30 ± 0.53	18.04 ± 0.70	16.67 ± 0.41	17.08
	SCS	22.03 ± 0.72	17.12 ± 0.69	17.93 ± 0.46	19.39 ± 0.52	16.53 ± 0.74	18.60
	SCCh	16.99 ± 0.88	12.90 ± 0.79	14.20 ± 0.34	10.01 ± 0.43	10.73 ± 0.23	12.97
	SCE	15.18 ± 0.66	12.11 ± 0.57	11.43 ± 0.73	8.02 ± 0.43	11.10 ± 0.72	11.57
	SCJ	20.98 ± 0.78	16.32 ± 0.31	15.71 ± 0.62	18.99 ± 0.67	16.64 ± 0.79	17.73
	SCF	20.33 ± 0.87	15.65 ± 0.83	14.53 ± 0.74	14.52 ± 0.24	13.45 ± 0.53	15.69
	SCWG	21.36 ± 0.63	17.07 ± 0.58	15.64 ± 0.64	17.44 ± 0.28	15.80 ± 0.74	17.46
	SCI	22.33 ± 0.33	16.36 ± 0.68	15.67 ± 0.50	15.43 ± 0.23	14.58 ± 0.41	16.87
	$\bar{x}$	19.48	15.66	15.17	15.23	14.44	
	LSD p < 0.05	I – 0.430, II – 0.340, I × II – 0.961					
b*	SC0	3.89 ± 0.69	5.52 ± 0.40	4.79 ± 0.58	6.46 ± 0.42	7.06 ± 0.19	5.54
	SCS	6.38 ± 0.85	5.59 ± 0.33	5.07 ± 0.64	7.46 ± 0.42	6.72 ± 0.13	6.24
	SCCh	3.32 ± 0.91	2.22 ± 0.13	2.50 ± 0.27	1.55 ± 0.11	1.86 ± 0.16	2.29
	SCE	3.21 ± 0.59	1.60 ± 0.22	2.25 ± 0.13	1.33 ± 0.15	3.58 ± 0.45	2.39
	SCJ	5.75 ± 0.58	4.46 ± 0.44	8.42 ± 0.84	8.71 ± 0.36	6.71 ± 0.40	6.81
	SCF	10.68 ± 0.59	8.85 ± 0.77	8.17 ± 0.61	8.14 ± 0.15	8.44 ± 0.33	8.86
	SCWG	6.92 ± 0.56	6.71 ± 0.42	7.05 ± 0.22	7.63 ± 0.45	9.42 ± 0.96	7.55
	SCI	7.58 ± 0.79	4.63 ± 0.10	4.24 ± 0.40	5.82 ± 0.13	5.16 ± 0.65	5.48
	$\bar{x}$	5.97	4.95	5.31	5.89	6.12	
	LSD p < 0.05	I – 0.282, II – 0.223, I × II – 0.630					

Explanatory notes as in Tab. 2. / Objaśnienia jak pod Tab. 2.

In all the evaluated jams, the values of a* parameter, reflecting the intensity of the red colour, ranged from 11.57 to 18.60 (Tab. 3). Compared to the SC0 jams, the values of a* parameter recorded in the SCJ and SCS jams were significantly higher. On the other hand, in the jams with added flax seeds, chokeberry and black elderberry, the proportion of the red colour decreased, whereas in the SCWG and SCI jams the differences were insignificant. It was revealed, however, that storing the jams at higher temperatures generally reduced the proportion of the red colour. This is congruent with the findings by Legua et al. [16] who observed a decrease in a* parameter in the pomegranate jam stored at a higher temperature.

The values of b* parameter were also higher than zero, this indicates the intensity of the yellow colour (Tab. 3). In the SC0 jam the average value of this parameter was 5.54. A low proportion of the yellow colour was found in the jams with added black chokeberry (2.29) and elderberry (2.39). In the remaining jams, in turn, the yellow colour (b*) increased by 13 ÷ 60 % compared to the SC0 jams. In the majority of jams the proportion of the yellow colour decreased throughout the storage period, b* value was generally higher in the jams stored at 20 ºC than in those kept at 10 ºC, probably owing to the degradation of anthocyanin and the formation of yellow-coloured compounds [17].

All the evaluated jams were characterized by intense and vibrant colour (C*), except for those with black chokeberry and elderberry, which were the darkest, exhibiting the lowest C* value, 20 and 27 % respectively, compared to the control sample (SC0) – Tab. 4. Chokeberry is a rich source of anthocyanins (4.60 ÷ 14.8 mg/g f.w.), which are responsible for the intense dark colour of fruit. Similar properties characterize black elderberry fruit [18]. The jams coded as SCS, SCJ, SCF and SCWG had a more intense colour than the control sample; the inulin added did not affect the C* value.

An anthocyanin-rich raw material added to the product lowers the h^o value and therefore the value of this parameter in the jams with added chokeberry and elderberry was 38 % and 27 % lower, respectively, than in the SC0 jams. In this case the colour shifted towards red-purple. This confirms the findings of Kirca et al. [19], who reported lower values of the h^o parameter in the jams with black carrot concentrate added. The authors mentioned above also observed an increase in this parameter during storage, which was even higher at higher temperatures. On the other hand the jams coded as SCS, SCJ, SCF, SCWG and SCI had higher h^o values which correspond to higher b* values and indicates a shift in the colour towards yellow.

In order to link the perception of colour by human eye with the numerical description of instrumental results, the International Commission on Illumination (CIE) has introduced the concept of the standard observer, who represents the average person with normal colour perception. The human perception of the colour of two samples can be inferred from the colour difference (ΔE*). Colour difference can be interpreted as follows: 0 < ΔE* < 1 – differences in colour are unrecognizable by a standard observer, 1 < ΔE* < 2 – only an experienced observer can perceive the difference, 2 < ΔE* < 3.5 – an inexperienced observer is able to perceive the differences, 3.5 < ΔE* < 5 – every observer can easily see the difference and ΔE* > 5 – an observer recognizes two different colours [20].

Table 4. Values of chroma (C*), hue angle (h°) and colour (ΔE*) of sour cherry jams
Tabela 4. Wartości nasycenia (C*), tonu (h°) i całkowitej różnicy barwy (ΔE*) dżemów wiśniowych

Parameter Parametr	Sample Próba	Storage duration at 10 °C and 20 °C [months] Czas składowania w temp. 10 i 20 °C [miesiące] 0	6 temp. 10 °C	6 temp. 20 °C	12 temp. 10 °C	12 temp. 20 °C	$\overline{x}$
C*	SC0	17.14 ± 0.99	11.51 ± 0.63	16.47 ± 0.52	18.44 ± 0.82	17.77 ± 0.43	16.26
	SCS	25.18 ± 0.91	17.97 ± 0.64	17.85 ± 0.52	20.16 ± 0.72	17.66 ± 0.85	19.76
	SCCh	16.48 ± 0.54	12.89 ± 0.66	14.54 ± 0.35	10.13 ± 0.44	10.74 ± 0.36	12.95
	SCE	14.37 ± 0.66	12.26 ± 0.57	11.45 ± 0.85	8.09 ± 0.23	13.09 ± 0.76	11.85
	SCJ	21.28 ± 0.97	19.58 ± 0.32	17.82 ± 0.58	20.85 ± 0.73	17.35 ± 0.76	19.37
	SCF	30.31 ± 0.80	16.06 ± 0.55	19.77 ± 0.72	19.70 ± 0.35	17.76 ± 0.48	20.72
	SCWG	22.16 ± 0.75	22.91 ± 0.66	17.18 ± 0.76	18.79 ± 0.31	17.64 ± 0.47	19.74
	SCI	22.74 ± 0.33	18.27 ± 0.80	12.50 ± 0.62	11.30 ± 0.65	17.35 ± 0.65	16.43
	$\overline{x}$	21.21	16.43	15.95	15.93	16.17	
	LSD $p < 0.05$	I – 0.444 , II – 0.321, I × II – 0.993					
h°	SC0	12.26 ± 0.80	10.42 ± 0.78	16.59 ± 0.64	19.94 ± 0.73	20.50 ± 0.13	15.94
	SCS	17.62 ± 0.63	17.89 ± 0.32	14.74 ± 0.66	21.27 ± 0.70	20.90 ± 0.37	18.49
	SCCh	12.80 ± 0.71	9.53 ± 0.49	10.31 ± 0.56	8.88 ± 0.37	8.00 ± 0.42	9.90
	SCE	11.40 ± 0.54	9.98 ± 0.20	11.00 ± 0.59	9.46 ± 0.21	16.10 ± 0.43	11.59
	SCJ	16.29 ± 0.79	14.98 ± 0.48	22.78 ± 0.88	24.68 ± 0.67	18.70 ± 0.75	19.49
	SCF	20.84 ± 0.92	21.60 ± 0.61	23.33 ± 0.95	24.52 ± 0.20	27.81 ± 0.96	23.62
	SCWG	17.07 ± 0.95	21.32 ± 0.60	24.42 ± 0.20	23.68 ± 0.80	30.58 ± 0.71	23.41
	SCI	18.01 ± 0.68	12.46 ± 0.80	13.41 ± 0.43	15.49 ± 0.36	23.69 ± 0.39	16.61
	$\overline{x}$	15.78	14.77	17.07	18.49	20.78	
	LSD $p < 0.05$	I – 0.405, II – 0.321, I × II – 0.907					
ΔE*	SC0						
	SCS	6.20 ± 0.65	3.31 ± 0.44	1.85 ± 0.75	2.26 ± 0.58	1.36 ± 0.45	2.79
	SCCh	1.54 ± 0.45	5.89 ± 0.78	3.82 ± 0.79	10.17 ± 0.65	8.26 ± 0.47	6.79
	SCE	1.70 ± 0.53	6.89 ± 0.80	5.69 ± 0.80	11.77 ± 0.78	6.78 ± 0.47	7.54
	SCJ	8.66 ± 0.30	4.20 ± 0.78	5.35 ± 0.43	3.63 ± 0.97	2.26 ± 0.92	4.82
	SCF	14.61 ± 0.80	13.05 ± 0.24	10.76 ± 0.20	9.70 ± 0.68	10.71 ± 0.30	11.77
	SCWG	12.39 ± 0.44	10.47 ± 0.55	8.22 ± 0.89	7.33 ± 0.54	8.92 ± 0.66	9.47
	SCI	6.87 ± 0.95	1.89 ± 0.40	1.96 ± 0.43	3.94 ± 0.89	3.18 ± 0.62	3.57
	$\overline{x}$	7.42	7.69	5.38	6.97	5.92	
	LSD $p < 0.05$	I – 0.583, II – 0.492, I × II – 1.303					

Explanatory notes as in Tab. 2. / Objaśnienia jak pod Tab. 2.

The raw materials studied had a significant effect on the colour of the jams, which they were added to. The biggest colour differences (ΔE* above 6) were observed in the SCCh, SCE, SCWG and SCF jams; their colour could be perceived as two different colours (Tab. 4). After 6-month storage of the jams the differences resulting from the storage temperature became apparent. In the jams stored at refrigeration temperatures the ΔE* value did not differ significantly compared to the jams right away after production, however in those stored at room temperature it was substantially lower. A similar trend was observed after 6 months of successive storage. An increase in the colour difference observed between the samples stored at a room temperature and the remaining ones resulted from bigger changes in the individual colour parameters noted at higher temperatures.

Sensory evaluation of sour cherry jams

For both the consumers and the food producers, the sensory properties of food products are of utmost importance as they directly relate to the quality of a product as well as to the consumer choice and acceptance [8].

Acceptability of the cherry jams analysed was determined using a 5-point scale for sensory evaluation (Tab. 5). Compared to the control sample, the sensory characteristics of the other jams did not significantly deteriorate when a part of sucrose was replaced with steviol glycoside, the only exception was the consistency of that SCS jam that was softer. The taste of this jam evaluated immediately after production was rated 5.0 points, however after 12 months of storage a slight decrease was observed in the intensity of the sour cherry taste.

In the SCCh and SCE jams the fruit added caused the sour cherry taste to become less perceptible because the taste and aroma of chokeberry and elderberry prevailed; in this way the products gained new sensory characteristics. The Japanese quince fruit added to the jam made its taste refreshing and slightly acidic. The sour cherry jams with fruits studied received the highest scores in the sensory evaluation and no significant differences between all the samples were reported; this referred also to the jams stored for 12 months at room and refrigeration temperatures.

The colour of the cherry jams with flax seeds and wheat germs immediately after production was rated lower compared to other jams because the shade of the product was grey. The evaluation score for this quality factor significantly decreased with the storage duration. Compared to the jams evaluated immediately after production, the jams with added SCF and SCWG were awarded lower scores: 12 % and 15 %, respectively. Moreover, compared to the jam without plant additives (control sample), immediately after production significant changes were reported in the aroma of the product containing wheat germs. After 12-month storage of those jams a further deterioration of their aroma was found, therefore the evaluation scores for this parameter decreased 36 %, compared to the non-stored jams. The wheat germs added reduced the intensity of the sour cherry aroma; instead a farinaceous aroma was dominant. Similarly the aroma of the SCWG jam samples analysed after 12-month storage deteriorated significantly. However this parameter of the jam samples stored at a room temperature was rated significantly lower than of those stored at a refrigeration temperature. There is considerable evidence in the literature that the temperature plays a major role in changes in food quality during storage [21]. Selvamuthukumaran and Khanum [22] reported

Table 5. Sensory quality of sour cherry jams [scores]
Tabela 5. Jakość organoleptyczna dżemów wiśniowych [punkty]

Quality factor / Wyróżnik jakości	Weighting coefficients / Współczyn. ważkości	Storage time [months] / Czas składowania [miesiące]	Sample / Temperature of storage / Próba / Temperatura przechowywania															
			SC0		SCS		SCCh		SCE		SCJ		SCF		SCWG		SCI	
			10 °C	20 °C	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C
1. External appearance of the product / Wygląd zewnętrzny produktu: a) surface (syneresis) powierzchnia (synereza)	2	0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
		6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
		12	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
b) structure (disposition of fruit parts in the content of jam) struktura (rozkład części owoców w masie dżemu)	3	0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.0	4.0	5.0	5.0
		6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.2	4.2	4.2	4.2	5.0	5.0
		12	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.0	5.0	5.0	3.5	3.5	3.5	3.5	4.5	4.5
c) colour / barwa	4	0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.6	4.6	4.6	4.6	5.0	5.0
		6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.6	4.5	4.6	4.5	5.0	5.0
		12	5.0	5.0	4.8	4.8	5.0	5.0	4.5	5.0	4.8	4.8	4.1	4.0	3.9	3.9	5.0	5.0
2. Consistency / Konsystencja	3	0	5.0	5.0	4.5	4.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
		6	5.0	5.0	4.3	4.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
		12	5.0	5.0	4.1	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.2	4.2	4.5	4.5	5.0	5.0
3. Aroma (type and desirability) Zapach (rodzaj i pożądalność)	4	0	5.0	5.0	5.0	5.0	5.0	4.8	5.0	5.0	5.0	5.0	5.0	5.0	4.7	4.7	5.0	5.0
		6	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	4.4	4.4	4.7	4.7
		12	5.0	5.0	4.8	4.7	4.8	4.7	4.9	4.9	4.9	4.9	4.0	4.0	3.0	3.0	4.5	4.5

4. Taste (type and desirability) Smak (rodzaj i pożądalność)	4	0 6 12	5.0 5.0 5.0	5.0 5.0 5.0	5.0 5.0 4.6	5.0 5.0 4.6	5.0 5.0 4.9	5.0 5.0 4.9	5.0 5.0 5.0	5.0 5.0 4.9	5.0 5.0 4.9	5.0 5.0 4.7	5.0 5.0 4.0	5.0 4.9 4.0	4.4 4.6 3.7	4.4 4.5 3.3	5.0 5.0 4.7	5.0 5.0 4.7
Final score Ocena końcowa	20	0 6 12	5.0 5.0 5.0	5.0 5.0 5.0	4.9 4.9 4.7	4.9 4.9 4.7	5.0 5.0 4.9	5.0 5.0 4.9	5.0 5.0 4.8	5.0 5.0 4.8	5.0 5.0 4.9	5.0 5.0 4.9	4.8 4.8 4.0	4.8 4.7 4.0	4.6 4.6 3.8	4.6 4.6 3.8	5.0 4.9 4.8	5.0 4.9 4.8
LSD $p < 0.05$ for final score LSD $p < 0,05$ oceny końcowej		0 6 12	0.06 0.12 0.26															
Total / Całkowite LSD $p < 0.05$			0.55															

Explanatory notes as in Tab. 2. / Objaśnienia jak pod Tab. 2.; n = 15.

that the colour, flavour and taste of the sea buckthorn jam stored remained better at a low temperature than at a room temperature.

Immediately after production the sour cherry jams with inulin were scored high (5.0 points). During storage the intensity of the sour cherry aroma decreased significantly, however it did not significantly affect the high final score (4.8 points).

Summarizing the jams with pro-health ingredients added, except for flax seeds and wheat germs, achieved very high scores in the general sensory evaluation compared to the control.

Conclusions

1. The sour cherry jams with added flax seeds and wheat germs were the hardest. During storage an increase was reported in the gel strength (F_e) in all the products.
2. In the jams the dominant colours were red (a*) and yellow (b*). The jams with added flax seeds and wheat germs were found the brightest (L*).
3. The results of this research study have proved that it is possible to replace part of sucrose with steviol glycoside without causing any deterioration of the sensory characteristics of the product.
4. The addition of chokeberry, elderberry, Japanese quince and inulin to the sour cherry jams had a beneficial effect on all the sensory features, which generally did not change after 12 months of storage.
5. The addition of flax seeds and wheat germ to the sour cherry jams caused the colour, aroma and taste to deteriorate, especially after the 12-month storage. In this case it would be recommended to reduce the storage period to 6 months.
6. Compared to storage of the jams at a room temperature (20 ºC), storing them at a refrigeration temperature (10 ºC) had a better effect on their colour and texture, although their sensory features were affected to a lesser degree.

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WPŁYW WARUNKÓW PRZECHOWYWANIA NA PARAMETRY TEKSTURY I JAKOŚĆ SENSORYCZNĄ DŻEMÓW WIŚNIOWYCH Z RÓŻNYMI DODATKAMI ROŚLINNYMI

S t r e s z c z e n i e

W pracy porównano parametry tekstury i barwy oraz wyróżniki jakości sensorycznej w niskosłodzonych dżemach wiśniowych, zarówno z prozdrowotnymi składnikami roślinnymi, jak i bez ich udziału (próba kontrolna). Badane dżemy wiśniowe zawierały dodatek owoców aronii, czarnego bzu, pigwowca japońskiego oraz nasiona lnu, zarodki pszenne i inulinę w ilości 6 ÷ 42 % masy wiśni. Zawartość sacharozy zmniejszono o 15 ÷ 48 % w wyniku zastąpienia jej glikozydami stewiolowymi. Produkty były analizowane bezpośrednio po produkcji oraz po 6 i 12 miesiącach składowania w temperaturze chłodniczej (10 °C) i pokojowej (20 °C). W dżemach dominowała barwa czerwona (a*) oraz żółta (b*). Najjaśniejsze były dżemy z dodatkiem pigwowca japońskiego, nasion lnu i zarodków pszennych. Dodatek owoców aronii i czarnego bzu spowodował znaczne przyciemnienie barwy dżemu. W składowanych dżemach zaobserwowano zmiany parametrów tekstury i barwy, przy czym w dżemach składowanych w 10 ºC zmiany te były mniejsze. W ocenie sensorycznej dżemy otrzymały wysokie noty, zarówno bezpośrednio po produkcji, jak i po 6-miesięcznym składowaniu (4,6 ÷ 5,0 pkt). Po 12-miesięcznym składowaniu dżemy zachowały nadal wysoką jakość (4,7 ÷ 5,0 pkt), z wyjątkiem dżemów z nasionami lnu i zarodkami, które uzyskały niższe noty (3,8 ÷ 4,0 pkt). Po analizie badanych prób wykazano, że korzystniejsze jest składowanie dżemów w niższej temperaturze, a w próbach wzbogaconych lnem i zarodkami pszennymi należy skrócić czas składowania do 6 miesięcy. Podsumowując, można stwierdzić, że zastosowane dodatki wzbogacające (aronia, czarny bez, pigwowiec, len, zarodki pszenne, inulina) mogą stanowić korzystną alternatywę dla tradycyjnych dżemów.

Słowa kluczowe: wiśnia, dżem, dodatki roślinne, tekstura, barwa, właściwości sensoryczne