NAUKI INŻYNIERSKIE I TECHNOLOGIE ENGINEERING SCIENCES AND TECHNOLOGIES
1(38) • 2022

e-ISSN 2449-9773

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Use of Courgette and Added Citrus Fruit for Jam Production

Wykorzystanie cukinii i dodatku owoców cytrusowych do produkcji dżemów

DOI: 10.15611/nit.2022.38.11
JEL Classification: L66, O31

Summary: Jams as sweet spreads occupy an important place among the processed products on offer. Despite the wide range of such products, courgette jams are absent. This vegetable, due to its sensory properties: light colour and delicate taste and smell, which can be easily modified with the addition of other components, seems to be a suitable raw material for their production. The aim of this study was to develop jams based on courgetti mixed with 30% of citrus fruits and to assess their impact on the quality of the product. The jams were produced in two versions: traditional with the addition of sugar and "light" with its substitute – xylitol. Color, pH, total extract, total acidity and content of bioactive compounds were determined in them. Sensory evaluation was carried out on a 5-point scale and their general acceptability on a 9-point hedonic scale. Studies have shown that the addition of lime, lemon and orange to the production of courgette jams allowed to obtain products with the best sensory properties and high nutritional value. For comparison, jams with the addition of grapefruit were distinguished by lower acceptability due to the perceptible bitterness of their taste.

Keywords: jam, courgette, citrus fruit, quality.

Streszczenie: Dżemy jako słodkie smarowidła zajmują ważne miejsce wśród produktów oferowanych przez przetwórstwo. Pomimo szerokiego asortymentu tych wyrobów brak jest jednak dżemów z cukinii. Warzywo to ze względu na swoje właściwości sensoryczne: jasną barwę, delikatny smak i zapach, które łatwo można modyfikować dodatkiem innych komponentów, wydaje się surowcem odpowiednim do produkcji dżemów. Celem badań było opra-

cowanie dżemów na bazie cukinii z 30-procentowym dodatkiem owoców cytrusowych oraz ocena ich wpływu na jakość produktu. Dżemy były wytwarzane w dwóch wersjach: tradycyjnej – z dodatkiem cukru, oraz „light" – z jego zamiennikiem: ksylitolem. Oznaczano w nich barwę metodą obiektywną, pH, ekstrakt ogólny, kwasowość ogólną i zawartość związków bioaktywnych. Przeprowadzono ocenę sensoryczną w skali 5-punktowej i zbadano ogólną ich akceptowalność w 9-punktowej skali hedonicznej. Badania wykazały, że dodatek limonki, cytryny i pomarańczy podczas produkcji dżemów z cukinii pozwala uzyskać produkty o najlepszych właściwościach sensorycznych i wysokiej wartości żywieniowej. Dla porównania dżemy z dodatkiem grejpfruta charakteryzowały się niższą od nich akceptowalnością ze względu na wyczuwalną goryczkę ich smaku.

Słowa kluczowe: dżem, cukinia, owoce cytrusowe, jakość.

1. Introduction

Jams are among products highly valued by consumers. The most frequently selected in our country are: strawberry, cherry, peach and blackcurrant (Kadzińska, Kadzińska, Jasiczek, Niemczuk, and Galus, 2013). On the world market, products of this type are also of great importance and the vast majority of them are fig, raspberry, orange, blackberry and mango jams.

Outside the European Union, the offered range of jams is more extensive due to the variety of raw materials used. Sweet potato, coconut, ginger and banana jams are popular in the Caribbean, while the market in Syria offers mulberry and rosehip jams. In other countries, apart from fruit jams, vegetable jams are also widespread, including – in Portugal – carrot, tomato and pumpkin jams (Marszałek, Wozniak, and Skapska, 2014). Currently, food producers, taking into account the health aspect of these products, are modifying their composition, reducing not only the calorific value (by approximately 25%), but also improving their nutritional value. Increasingly, they compose jams by combining various fruits that can improve their organoleptic properties, such as taste, smell and appearance (Shinwari and Rao, 2018), and instead of sucrose, they introduce its substitutes (polyols, e.g. xylitol or sorbitol). Their advantage is the slower absorption by the body and the fact that they do not cause a rapid increase in glucose levels (Di Monaco and Mi, 2018). Such jams are especially recommended in the diet of obese people, patients with diabetes and those who care about a slim figure. A typical commercial sweetener used in jams is sucralose, derived from sucrose, which has a taste profile very similar to it. Stevia is also used, which is a natural table-top sweetener based on steviol glycosides that naturally occur in the leaves of the Stevia rebaudiana Bertoni plant (De Souza, 2013; Gęsiński, Majcherczak, and Gozdecka, 2013).

Despite the rich variety of fruit jams offered in our country, it seems reasonable to produce new products with a modified composition, by replacing some fruit with vegetables. An example of such can be courgette jam. In terms of nutrition, courgette is an easily digestible vegetable, the composition of which contains bioactive

compounds important for humans (polyphenols, vitamins). Thanks to their presence, it has antioxidant, antibacterial, antidiabetic, anti-inflammatory and anticancer properties (Oloyede, Agbaje, Obuotor, and Obisesan, 2012).

The water content of courgette is about 94%. Due to the small amount of carbohydrates (2.3-3.2 g/100 g) and fat (1.3-3.2 g/100 g), it has a very low energy value (21-22 kcal in 100 g of dry matter). The protein content in 100 g ranges from 1-2.5 g, and the fibre content from 0.9-1.1 g (Douiri-Bedoui, 2011). Courgette is a rich source of minerals such as potassium (250 mg/100 g), phosphorus (32 mg/100 g), magnesium (22 mg/100 g) and calcium (15 mg/100 g), the concentration of which depends on the species, variety and maturity (Kunachowicz, Nadolna, Iwanow, and Przygoda, 1997; Salehi, Sharifi-Rad, Capanglu, and Adrar, 2019). Importantly, in its composition there are also present antioxidants such as: phenols, carotenoids, chlorophylls and ascorbic acid, and in smaller amounts: vitamin A, vitamin E, thiamine, niacin and vitamin B_5. The functional components of courgette are believed to play an important role in modifying the risk factors for many chronic diseases. In addition, a great advantage of courgette is that it does not accumulate heavy metals, including cadmium and nitrates (Pukszta, 2013).

For some time, courgette has become not only a significant product on the fresh food market, but also an important raw material for the production of vegetable preserves around the world, especially in Mediterranean countries and America (Kekuda, 2012).

In Poland, courgette pulp, despite its many advantages, is relatively little used in processing, Yet the culinary processing of courgette is of greater importance than industrial. It is used e.g. for casseroles, spaghetti and salads (Świetlikowska, 2006). Depending on the degree of ripeness, courgette are used as frozen, dried and canned vegetables, and especially recommended for preserves and pickles. Moreover, it seems to be a valuable raw material with untapped potential for the production of jams.

Therefore, the aim of the study was to evaluate the quality of courgette jams with the addition of citrus fruits (lime, lemon, orange, grapefruit) at a concentration of 30%, adding sugar and xylitol.

It was assumed that the use of courgette and modification of its composition with the addition of citrus fruits and the use of xylitol, apart from sugar, will allow the development of an innovative product that consumers may want.

2. Research material

Courgettes (*Cucurbita pepo*) of the Porter variety, purchased from the "Fabryka Warzyw" warehouse in Szczecin, from Spain, supplied by Unica Fresh S.L., were used for the study (Almería). The fresh raw material was distinguished by the dark green colour of the skin and light (creamy-yellow) pulp. Its average length was 22 cm and its weight was 400 g. The content of total extract in fresh courgettes was 5%, pH was 5.93, and total acidity 0.40 g/100 g.

As auxiliary raw materials for the production of courgette jams, which were purchased at the "Stokrotka" retail store in Szczecin, the following were used:

- Citrus fruits:
  - oranges (*Citrus sinensis*) of the Valencia variety originating from Zimbabwe, supplied by Baltic Klaipeda Fresh Fruit (Lalstu village). The fruits were distinguished by the orange colour of the skin and flesh. The total extract in the fruit was 12.0 and the pH was 3.6; total acidity 1.85 g/100 g;
  - lemons (*Citrus limon*) of the Interdonato variety, originating from Turkey, supplied by Unat Tarim Nakliyat Gida Insaat Petrol Sanayi Ve Ticaret Limited Sirketi (Manisa). The fruit had an intense yellow skin colour and the pulp was slightly yellow and aromatic. The extract content in the fruit was 11.7% and the pH was 2.3; total acidity 3.95 g/100 g;
  - grapefruit (*Citrus paradisi*) the Star Ruby variety, originating from Turkey, producer Arman Citrus Ltd. They were characterised by a bright orange colour of the skin and red pulp. Total fruit extract was 11% and pH 3.5; total acidity 2.2 g/100 g;
  - limes (*Citrus aurantifolia*) of the Tahiti variety from Brazil, whose supplier was Nature's Produce (Drwalew). The fruit had a thin green skin and the pulp was light yellow-greenish. Total extract was 11.5% and pH 1.8, total acidity 4.5 g/100 g.
- white, fine crystalline sugar – (fine KD granulation) from Pfeifer & Langen Polska S.A. (Poznań), used in the amount of 200 g for one batch of fruit prepared for the production of jam.
- xylitol – birch sugar, manufactured by Danisco Sweeterens from Finland, added in the amount of 240 g/for one batch of raw materials prepared for the production of jam;
- amidated apple pectin in the form of powder, belonging to the type of low-methylated pectins, produced in Switzerland, whose supplier in Poland is Batom® (Kraków). Used for jams in the amount of 1.5% per 100 g of jam weight;
- citric acid (acidity regulator) – Gellwe, produced by Food Care Sp. z o. o. in Zabierzów. Added in the control sample (without the addition of citrus fruits) in the production of jam in the amount of 2.0% per 100 g of jam weight to other jams, depending on the pH, at a level not higher than 0.5% per 100 g.

2.1. Preparation of courgette jams

Courgette jams with and without the addition of citrus fruits (control sample) were made according to the plan shown in Figure 1.

The courgettes were washed under running water, drained of excess water and peeled. Thus cleaned, the vegetables were cut into cubes and placed in a multicooker (Philips HD3037/70) using mild heating (80°C/15 min); after cooking, they blended

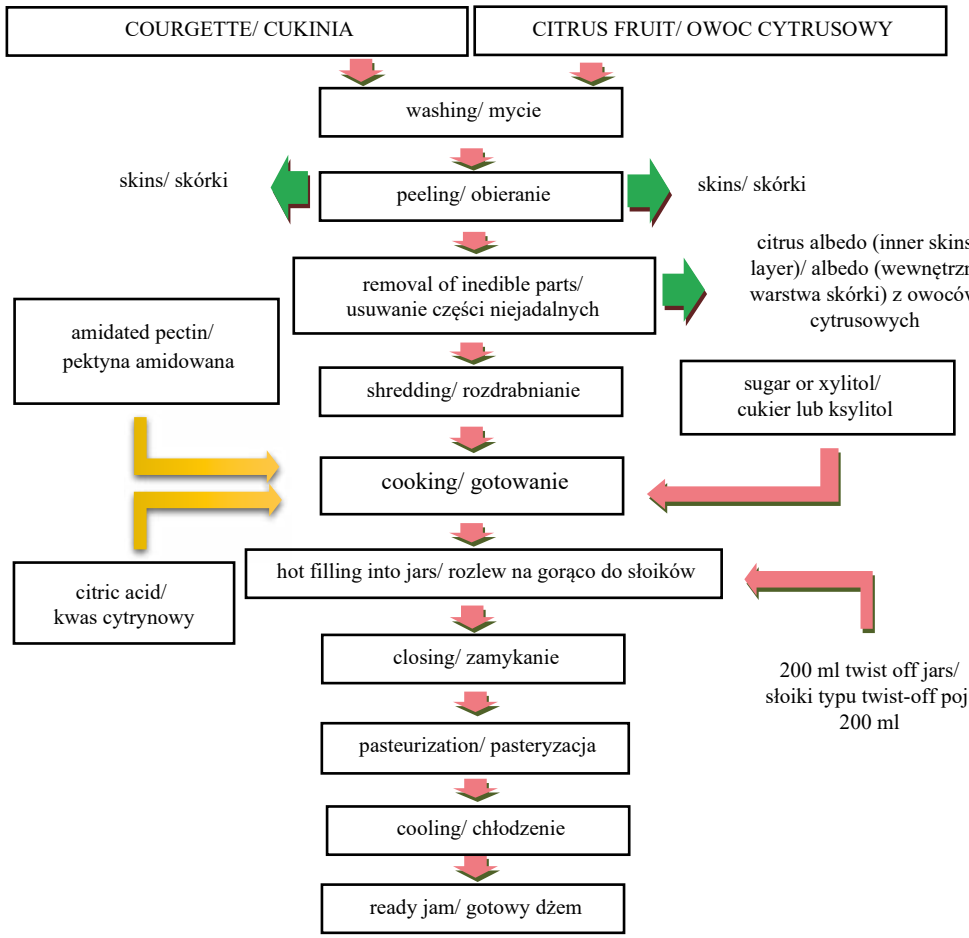


Fig. 1. Block diagram of the preparation of courgette jams with and without the addition of citrus fruits (control sample) in the sugar/ xylitol versions
Rys. 1. Schemat blokowy przygotowania dżemów z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Source/Źródło: own elaboration/opracowanie własne.

(Braun Multiquick 5 MQ 5045) for 1 minute, then the obtained uniform purée, 0.7 kg was weighed in five versions for each variant.

The citrus fruits, i.e. oranges, lemons, grapefruit and limes, after thorough washing, were peeled and the adhering outer skin and albedo (inner part of the skin) were removed. After discarding the ballast parts, each fruit was divided into pieces to extract the juicy pulp. The pulp obtained in this form from each fruit was added in the amount of 30% in relation to the vegetable mass, which was the basic charge

(70%). In the control sample, the content of courgettes was 100% and the pulp of citrus fruits was 0% (the sample without the addition of citrus fruits).

From the prepared courgettes and citrus fruits, 5 jams were developed for each version of the sweetener (sugar or xylitol) in three repetitions:

I: control sample (without the addition of citrus fruit) courgette 1000 g;
II: 700 g courgette and 30% orange (300 g);
III: 700 g courgette and 30% lemon (300 g);
IV: 700 g courgette and 30% grapefruit (300 g);
V: 700 g courgette and 30% lime (300 g).

In the case of jam I (control sample – without the addition of citrus fruits), weighed courgette in the amount of 1000 g, after slightly boiling it, sugar in the amount of 200 g or xylitol 240 g was added in two divided parts: the first half (100 g – sugar) or (120 g – xylitol), and the second half after 10 minutes (100 g – sugar) or (120 g – xylitol), after another 15 minutes – pectin (15 g), and finally citric acid (15 g). Everything was cooked until slightly thickened. In the preparation of the remaining jams II, III, IV and V with the addition of citrus fruit, 300 g of purified citrus fruit pulp was added to the weighed mass of grated courgette (700 g) and the whole was boiled. Then, sugar or xylitol in the amounts as in the control sample (without the addition of citrus fruit) were added to the vegetable and fruit mass, and after 15 minutes pectin (15 g). The whole was cooked until the mass thickened slightly. The total heat treatment time of the jam was 30 minutes at 95°C. The mass of each version obtained in this way was poured into 185 g jars, tightly closed and pasteurised in Koch's "PREMED" apparatus at the temperature of 85ºC/15 minutes. After cooling down to the temperature of 18°C, the jams were stored for 2 weeks in the warehouse of the university at the Department of Fish, Plant and Gastronomy Technology.

3. Research methods

In jams, the following was determined:

- **Colour** – by the objective method on the NH 310 apparatus (Shenzhen Technology Co., Ltd.; China). Colour components were determined: L* (brightness); a* (red/+) or (green/–) and b* (yellow/+) or (blue/–) in five replicates from which the mean value and standard deviation (Xav±SD) were calculated. The overall difference in colour (ΔE) was also measured between the control sample (without the addition of citrus fruits) and the jams with their addition (Pathare, Opara, and Al-Said, 2013). All measurements were made with SCI geometry, CIE L*a*b*C*h* colour space, using an 8 mm diameter measurement aperture and D65 illuminator and a CIE 10° standard observer. Before each measurement, the camera was calibrated against a white standard. After thorough mixing, the jam sample was transferred to a quartz cuvette in the amount of 85 g, inserted into the universal attachment directly connected to the colorimeter and read.

- **Total extract –** in accordance with PN-90/A-75101/02. The measurements were carried out using a RBR50-ATC telescope refractometer with an accuracy of 0.5% (Merazmet). The mean value and standard deviation (Xaver±SD) were calculated from the obtained data.
- **pH** – by potentiometric method using pH-meter ADWA AD 12 (Romania). Samples of the jams were placed in 25 cm^3 beakers and pH was measured in triplicate. The mean value and standard deviation (Xaver±SD) were calculated from the obtained data.
- **Total acidity** - according to PN-90/A-75101/04 in three repetitions and was calculated in g/100 g of product weight converted to citric acid.
- **Ascorbic acid –** in accordance with PN-90A-75101/11. Measurements using the titration method were carried out in three repetitions, from which the mean value and standard deviation (Xav±SD) were calculated. The content of ascorbic acid was calculated in (mg/100 g of product).
- **Total polyphenolic compounds –** by Turkmen, Sari, and Velioglu (2005). 2.5 ml of 10% Folin-Ciocalteua reagent and after 5 minutes 2 ml of 7.5% Na_2CO_3 were added to methanol extracts of 0.5 ml. After thorough mixing, all samples were transferred to the darkroom for 2 hours. The absorbance of the samples was measured spectrophotometrically at a wavelength of 750 nm. The results were converted in mg of GAE gallic acid/100 g of sample weight in relation to the standard curve. Triplicate determinations were made for each sample.

The organoleptic evaluation of taste, smell, colour and consistency was carried out in the jams using the 5-point scale (1-bad, 2-insufficient, 3-sufficient, 4-good, 5-very good) (according to Baryłko-Pikielna and Matuszewska, 2009) with with the participation of a 10-person team properly trained in terms of sensory sensitivity (PN-ISO 5496:1997, PN-ISO 3972-1998). For a more accurate description of the taste and aroma characteristics of the products obtained, eight flavour characteristics were assessed (citrus fruit, sour, zucchini, sweet, bitter, refreshing, bland, astringent) and eight characteristics of smell (pleasant, citrus, sweet, zucchini, refreshing, sour, bland, different) on a 6-point scale (1-imperceptible, 2-very weak, 3-weak, 4-moderate, 5-clear, 6-very clear) (according to Baryłko-Pikielna and Matuszewska, 2009). In addition, the overall acceptability of the product was assessed on a 9-point hedonic scale in accordance with PN ISO4121:1998 (1 – extremely undesirable, 2 – very undesirable, 3 – undesirable, 4 – slightly undesirable, 5 – neither undesirable nor desirable, 6 – slightly desirable, 7 – desirable, 8-very desirable, 9-extremely desirable). The overall evaluation of the jams was calculated as a weighted average of individual partial evaluations, taking into account the following weighting factors: colour – 0.2, smell – 0.3, consistency – 0.2, and taste – 0.3. The obtained results were assigned to one of the quality classes: 5 – 4.5 points – very good quality, 4.4 α 3.5 points – good quality, 3.4 – 2.6 points – sufficient quality, 2.5 – 1, 6 points – insufficient quality, < 1.5 points – bad quality (Samotyja, Sielicka-Różyńska, and Klimczak, 2020) and the quality level of the tested jams was determined.

The statistical analysis of the obtained results was carried out using the Statistica® 12.0 PL package (StatSoft, 2012). Mean values and standard deviations were calculated and Tukey's post-hoc test was used to verify the significance of differences between the mean values. The critical significance level was $\alpha = 0.05$.

4. Results and discussion

The obtained results indicate that the jams that were the subject of the tests differed slightly or did not show statistically significant differences in the assessment of physicochemical parameters such as total extract, pH and total acidity. However, greater differences were noted in the content of selected bioactive ingredients (vitamin C and total polyphenols) as well as in the organoleptic evaluation of the finished products, which was influenced by the specific characteristics of the raw materials used for the tests. The analysed jams also showed statistically significant differences in colour, confirmed by the results of the objective colour parameters L*, a* and b*, as well as the determined value of ΔE*, presented in Table 1. When analysing the colour in terms of its objective assessment, it was observed that the addition of citrus fruits to zucchini jams favourably distinguished their appearance. This was also confirmed by the sensory assessment of colour, as presented in Table 1.

It is known from the literature that the plant dyes contained in citrus fruits, including e.g. carotenoids (β-carotene, lycopene) and chlorophylls seem particularly valuable due to their colouring properties (Aghajanzadeh, Ziaiifara, and Verkerkb, 2021). Hence, the use of fruits, which are their source, in this study allowed to improve the visual appearance of zucchini jams towards orange, slightly yellow--lime and slightly red. The results summarised in Table 1 show how the colour of jams is ultimately obtained depending on the addition of citrus fruits and which of them seems to profile their colour most effectively. Regarding the value of parameter L*, which determines the lightness of colour, it was noted that its value for jams sweetened with sugar ranged from 43.64 (with the addition of lemon) to 38.45 (with the addition of grapefruit). For comparison, the colour brightness of the control sample (without the addition of fruit) was L* = 41.35. In jams with the addition of xylitol, similarly to traditional jams with sugar, the lowest value of parameter L* = 39.63 was shown by the jam with the addition of grapefruit, and the highest L* = 46.25 for that with the addition of lemon. In the case of jams with xylitol, an increase in L* parameter was observed in all samples compared to those sweetened with sugar, which was confirmed by the visual assessment of their colour, which seemed to be slightly brighter in this version.

When analysing the yellowness of the assessed jams, its highest share was found in those prepared with the addition of orange, which was 23.52 (in the version with sugar) and 19.94 (in the version with xylitol) (Table 1). For the jams with the addition of grapefruit, the b* parameter reached the lowest values from 13.45 (sugar) to 12.70 (xylitol). The remaining sugar-sweetened jams did not differ statistically significantly

in terms of yellowness, similarly to those to which xylitol was added. Summing up, all the jams traditionally sweetened with sugar showed a higher share of yellowness in colour than those with xylitol at the level of 6% to 15% (Table 1). According to Choi, Kim, and Lee (2012), the colour and especially its durability may be affected

Table 1. Objective colour parameters of courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Tabela 1. Obiektywne parametry barwy dżemów z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Kind of jam/ Rodzaj dżemu	Versions/ Wersje			
	Sugar/ Cukier	Xylitol/ Ksylitol	Sugar/ Cukier	Xylitol/ Ksylitol
	Brightness L*/ Jasność L*		Redness a*/ Czerwoność a*	
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu	41.35 ± 0.25^{b1}	42.62 ± 0.35^{b2}	1.70 ± 0.15^{a1}	1.05 ± 0.25^{a2}
Courgette + orange/ Cukinia + pomarańcza	42.73 ± 0.38^{c1}	44.84 ± 0.85^{d2}	4.05 ± 0.22^{c1}	3.45 ± 0.14^{b2}
Courgette + lemon/ Cukinia + cytryna	43.64 ± 0.52^{d1}	46.25 ± 0,82^{e2}	2.15 ± 0.15^{b1}	1.95 ± 0.31^{a1}
Courgette + grapefruit/ Cukinia + grejpfrut	38.45 ± 0.32^{a1}	39.63 ± 0.42^{a2}	9.45 ± 0.60^{d1}	8.95 ± 0.42^{c2}
Courgette + lime/ Cukinia + limonka	42.61 ± 0.25^{c1}	43.82 ± 0,52^{c2}	2.45 ± 0.15^{b1}	1.92 ± 0.20^{a2}
	Yellowness b*/ Żółtość b*		Overall colour difference ΔE/ Ogólna różnica barwy ΔE	
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	17.84 ± 0,80^{b1}	16.21 ± 0.34^{b1}	……..	……
Courgette + orange/ Cukinia + pomarańcza	23.52 ± 0.50^{c1}	19.94 ± 0.45^{c2}	6.30 ± 0.05^{c1}	4.96 ± 0.24^{c2}
Courgette + lemon/ Cukinia + cytryna	18.25 ± 0.25^{b1}	17.31 ± 0.25^{b2}	2.37 ± 0.25^{b1}	3.89 ± 0.63^{b2}
Courgette + grapefruit/ Cukinia + grejpfrut	13.45 ± 0.22^{a1}	12.70 ± 0.35^{a2}	9.37 ± 0.35^{d1}	9.07 ± 0.42^{d1}
Courgette + lime/ Cukinia + limonka	18.31 ± 0.35^{b1}	16.71 ± 0.25^{b2}	1.54 ± 0.42^{a1}	1.56 ± 0.35^{a1}

The mean values marked vertically in the columns with different letters differ significantly at $\alpha = 0.05$./ Wartości średnie oznaczone w kolumnach różnymi literami różnią się istotnie przy $\alpha = 0,05$.

The mean values marked horizontally in rows with different numbers differ significantly at $\alpha = 0.05$./ Wartości średnie oznaczone poziomo w wierszach różnymi liczbami różnią się istotnie przy $\alpha = 0,05$.

Source/Źródło: own study/opracowanie własne.

by the content of ascorbic acid in the raw materials. This, in turn, confirms that the lower its level in products resulting from heat treatment and technological factors such as light and oxygen, the worse their colour. According to Naknaen (2015), the type of sweetener also affects the colour parameters. The addition of xylitol used in the research, which is not subject to Maillard reactions like sugar, allows to obtain a less changed colour, which is shown by the lower values of the a* and b* parameters obtained.

On the other hand, the values of the overall colour difference (ΔE) describing the changes in colour between the control sample (without the addition of fruit) and jams with the addition of fruit allowed to conclude that all of them differed significantly in the value of this parameter. The greatest influence on ΔE was linked to by the share of grapefruit in courgette jams and the smallest share of lime, regardless of their sugar/xylitol version.

Table 2 presents the results of the total extract of the assessed jams. The content of the extract largely determines the nutritional quality and sensory characteristics of the product (Flis-Kaczykowska and Dmowski, 2020). The control sample (without the addition of fruit) showed a lower value of the total extract, regardless of the sugar/xylitol version, unlike jams with the addition of citrus fruits. Jams with the addition of oranges were distinguished by the highest total extract, the value of which was similar in both sugar/xylitol versions. Jams with the addition of lemon, grapefruit and lime did not differ significantly in the total extract, the value of which was lower than jams with orange by 5%, regardless of the assessed sugar/xylitol versions. All the tested jams me the total extract content in accordance with the guidelines for low-sugar jams, whicht

Table 2. The content of total extract [%] in courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Tabela 2. Zawartość ekstraktu ogólnego [%] w dżemach z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Kind of jam/ Rodzaj dżemu	Versions/ Wersje	
	Sugar/ Cukier	Xylitol/ Ksylitol
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	28.85 ± 0.00^{a1}	28.55 ± 0.25^{a1}
Courgette + orange/ Cukinia + pomarańcza	38.25 ± 0.00^{c1}	38.85 ± 0.25^{c1}
Courgette + lemon/ Cukinia + cytryna	36.12 ± 0.25^{b1}	36.82 ± 0.00^{b1}
Courgette + grapefruit/ Cukinia + grejpfrut	36.45 ± 0.25^{b1}	36.31 ± 0.25^{b1}
Courgette + lime/ Cukinia + limonka	36.25 ± 0.25^{b1}	36.0 ± 0.00^{b1}

The mean values marked vertically in the columns with different letters differ significantly at $\alpha = 0.05$./Wartości średnie oznaczone w kolumnach różnymi literami różnią się istotnie przy $\alpha = 0{,}05$.

The mean values marked in the rows with the index 1 do not differ significantly at $\alpha = 0.05$./Wartości średnie oznaczone w wierszach indeksem 1 nie różnią się istotnie przy $\alpha = 0{,}05$.

Source/Źródło: own study/opracowanie własne.

assume that its content should be at the level of 28% to 50% (Jarczyk and Płocharski, 2010; Rozporządzenie MRiRW 1398 z dnia 29 lipca 2003 …).

Considering pH assessment, in the tested jams made from courgette alone (without the addition of citrus fruits) sweetened with sugar or xylitol, its value was 4.30 and 4.35 (Table 3). For comparison, the pH of these jams did not differ statistically significantly from the pH values of jams with the addition of orange and grapefruit, regardless of the sugar/xylitol version. The lowest average pH value was found in jams with the addition of lime, which for those sweetened with sugar was 3.35 and for xylitol 3.62. Similarly, jams with the addition of lemon reached a pH similar to lime jams and did not differ statistically significantly (Table 3). The pH values of all the assessed jams were within the guidelines for low-sugar jams (Jarczyk and Płocharski, 2010). According to research by Ullah et al. (2017), the pH in carrot jams, in which the share of apple was from 10% to 50%, ranged from 3.58 to 3.65.

Table 3. pH of courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Tabela 3. pH dżemów z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Kind of jam/ Rodzaj dżemu	Versions/ Wersje	
	Sugar/ Cukier	Xylitol/ Ksylitol
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	4.30 ± 0.02^{b1}	4.35 ± 0.02^{b1}
Courgette + orange/ Cukinia + pomarańcza	4.26 ± 0.01^{b1}	4.30 ± 0.01^{b1}
Courgette + lemon/ Cukinia + cytryna	3.50 ± 0.08^{a1}	3.75 ± 0.01^{a1}
Courgette + grapefruit/ Cukinia + grejpfrut	4.05 ± 0.01^{b1}	4.17 ± 0.02^{b1}
Courgette + lime/ Cukinia + limonka	3.35 ± 0.02^{a1}	3.62 ± 0.02^{a1}

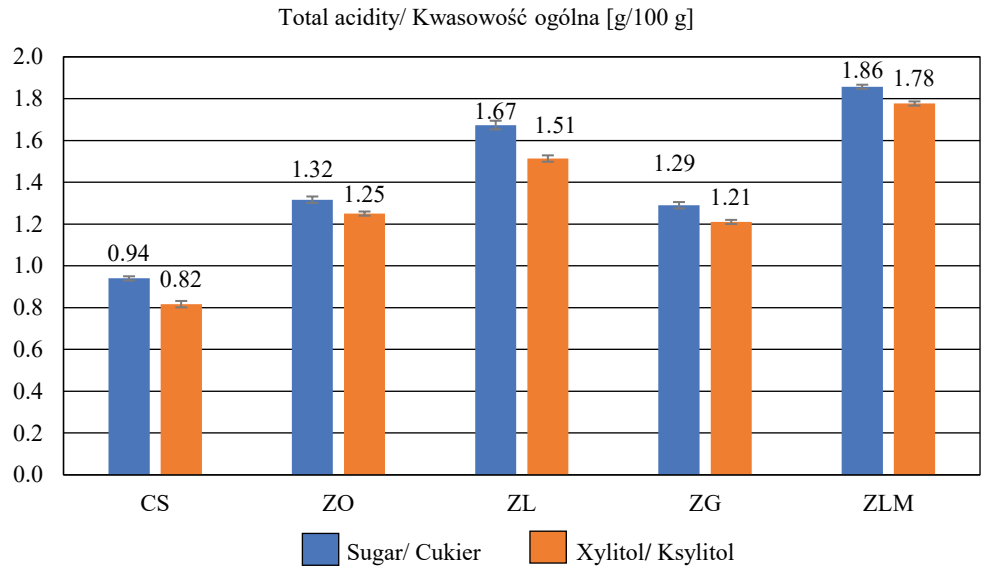
The mean values marked vertically in the columns with different letters differ significantly at $\alpha = 0.05$./Wartości średnie oznaczone w kolumnach różnymi literami różnią się istotnie przy $\alpha = 0{,}05$.

The mean values marked in the rows with the index 1 do not differ significantly at $\alpha = 0.05$./Wartości średnie oznaczone w wierszach indeksem 1 nie różnią się istotnie przy $\alpha = 0{,}05$.

Source/Źródło: own study/opracowanie własne.

Comparing the total acidity of the evaluated products, it was found that courgette jams constituting the control sample (without the addition of citrus fruits) had the lowest acidity compared to the others (Figure 2).

However, the acidity of these jams, regardless of the sugar/xylitol version, ranged from 0.94 g/100 g to 0.82 g/100 g and was in line with the recommendations for low-sugar jams (Flaczyk et al., 2011). Jams with the addition of orange and grapefruit, regardless of the sugar/xylitol version, demonstrated a slightly higher total acidity compared to the control sample (without the addition of fruit). The highest total acidity of 1.86 g/100 g for the version with sugar and 1.78 g/100 g for the version



Abbreviations used/ Objaśnienie skrótów: CS – control sample (without the addition of citrus)/ Próba kontrolna bez dodatku cytrusa; ZO – courgette + orange/ cukinia + pomarańcza; ZL – courgette + lemon/ cukinia + cytryna; ZG – courgette + grapefruit/ cukinia + grejpfrut; ZLM – courgette + lime/ cukinia + limonka.

Fig. 2. Total acidity [g/100 g] of courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Rys. 2. Kwasowość ogólna [g/100 g] dżemów z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Source/Źródło: own study/opracowanie własne.

with xylitol was found in jams with the addition of lime. A similarly high acidity, but slightly lower than lime by 10% (in the version with sugar) and 15% (in the version with xylitol), was found in jams with the addition of lemon. The differences in the research material resulted from the share of raw materials with a different content of organic acids. The lower acidity of jams made from zucchini alone is the result of the lack of organic acids in free form in the composition of the raw material, which, in turn, are abundant in fruits (Oszmiański and Sożyński, 2001). In the authors' own research, the acidity of fresh courgette was 0.30 g/100 g and was close to 0.32 g/100 g obtained by Tejada et al. (2020). The addition of citric acid in the case of low-acid raw materials is necessary to ensure proper gelation conditions (Awulachew, 2021). Acidification of courgette jam with the addition of citric acid was associated not only with increasing the acidity of the product, but also with improving its taste. In the organoleptic assessment, although the samples differed in the degree of perceptibility of the sour taste, for the control sample (without the addition of fruit), the sour taste was noticeable to a moderate degree.

When analysing jams in terms of the content of selected bioactive ingredients, such as vitamin C and total polyphenolic compounds, it was found that the addition of citrus fruits increased their nutritional value, which is confirmed by the results presented in Table 4 and Figure 3.

Of the citrus fruits used in this study, according to the literature, the highest content of ascorbic acid is found in oranges from 56 mg/100 g to 58 mg/100 g (Najwa and Azlan, 2017). In other fruits, the content of vitamin C is at the level of lemons (49-51 mg/100 g), grapefruit (38-47 mg/100 g) (Bungau, Fodor, Ţiţ, and Szabó, 2011; Cioroi, 2006) and limes (22.7 42.5 mg/100 g (Popova, 2019; Cherbrolu et al., 2012). Taking into account the level of vitamin C in citrus fruits, their introduction to courgette jams resulted in an increase in its level in all analysed cases. The highest content of vitamin C was found in jams with orange for the version with sugar, its amount was 16.51 mg/100g, and for the version with xylitol, it was 16.85 mg/100 g (Table 4), 6.25 mg/100 g and 7.02 mg/100 g. For comparison, the addition of orange increased the content of this compound in sugar-sweetened courgette jam by 62% and in xylitol-sweetened jam by 58.34% In other jams for the version with sugar, the content of vitamin C ranged from 15.44 mg/100 g (with lemon juice) to 11.01 mg/100 g (with the addition of lime). In the case of jams with xylitol, the content of vitamin C with the addition of these fruits was similar (Table 4). For comparison, in pumpkin jams with 30% of quince and strawberry fruits examined by Nawirska-Olszańska et al. (2010), the content of vitamin C was 10.39 mg/100 g and 9.36 mg/100 g. It was therefore lower than the level obtained in the tested courgette jams with the addition of citrus fruits.

Table 4. Ascorbic acid content [mg/100 g] in courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Tabela 4. Zawartość kwasu askorbinowego [mg/100 g] w dżemach z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ ksylitol

Kind of jam/ Rodzaj dżemu	Versions/ Wersje	
	Sugar/ Cukier	Xylitol/ Ksylitol
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	6.25 ± 0.58^{a1}	7.02 ± 0.58^{a2}
Coiurgette + orange/ Cukinia + pomarańcza	16.51 ± 0.58^{e1}	16.85 ± 0.58^{e1}
Courgette + lemon/ Cukinia + cytryna	15.44 ± 0.00^{d1}	15.68 ± 0.58^{d1}
Courgette + grapefruit/ Cukinia + grejpfrut	12.93 ± 0.58^{c1}	13.10 ± 0.58^{c1}
Courgette + lime/ Cukinia + limonka	11.01 ± 0.50^{b1}	11.21 ± 0.58^{b1}

The mean values marked vertically in the columns with different letters differ significantly at $\alpha = 0.05$. Wartości średnie oznaczone w kolumnach różnymi literami różnią się istotnie przy $\alpha = 0{,}05$.

The mean values marked in the rows with the index 1 do not differ significantly at $\alpha = 0.05$. Wartości średnie oznaczone w wierszach indeksem 1 nie różnią się istotnie przy $\alpha = 0{,}05$.

Source/Źródło: own study/opracowanie własne.

When assessing the content of polyphenolic compounds in jams, the lowest level was found in the control sample (without the addition of citrus fruit), which was 33 mgGAE/100 g for the version with sugar and 30 mgGAE/100 g for the version with xylitol (see Figure 3). The highest content of these ingredients, regardless of the sugar/xylitol version, was found in jams with the addition of grapefruit. The content of polyphenolic compounds with the addition of this fruit was 46.6 mg GAE/100 g in sugar-sweetened jams and 48.8 mgGAE/100 g in jams sweetened with xylitol). For comparison with the control sample, the addition of grapefruit enriched courgette jams with these ingredients by 29% (for the version with sugar) and 38% (for the version with xylitol), respectively. With regard to the remaining sugar-sweetened jams with the addition of citrus fruits, the content of total polyphenolic compounds ranged from 37 mgGAE/100 g (with the addition of lemon) to 41.4 mgGAE/100 g (with the addition of lime). For comparison, in jams sweetened with xylitol their amount was slightly lower and reached the same level for the addition of lemon and lime, about 35 mgGAE/100 g, while for the addition with orange it was higher and amounted to 43.4 mgGAE/100 g. In turn, Nawirska-Olszańska et al. (2010) showed the content of polyphenolic compounds at the level of 25.75 mgGAE/100 g and 36.55 mgGAE/100 g in pumpkin jams with 30% of strawberry and dogwood.

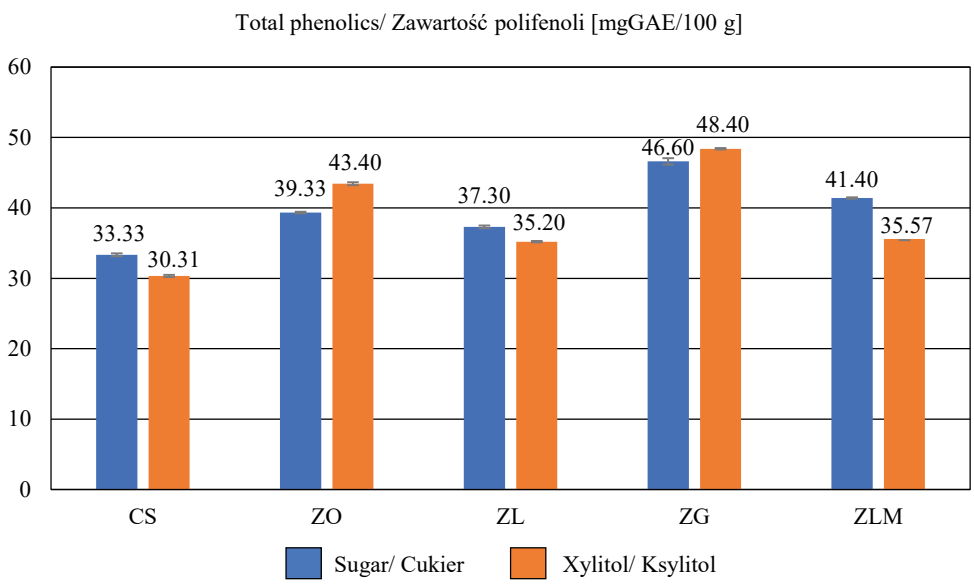


Fig. 3. The content of total polyphenolic compounds [mgGAE/100 g] in courgette jams with and without the addition of citrus fruits (control sample) in sugar/xylitol versions
Rys. 3. Zawartość związków polifenolowych ogółem [mgGAE/100 g] w dżemach z cukinii z dodatkiem owoców cytrusowych i bez ich dodatku (próba kontrolna) w wersjach cukier/ksylitol

Source/Źródło: own study/opracowanie własne.

However, in other studies (Rejeb, Dhen, Kassebi, and Gargouri, 2020), the content of total polyphenols in jellies prepared on the basis of citrus fruits alone ranged from 123.16 mgGAE/100 g to 192.76 mgGAE/100 g.

The organoleptic evaluation of the obtained zucchini jams with the addition of citrus fruits was of great importance for the entire research undertaken.

On the basis of the average values of such distinguishing features as colour, aroma and texture assessed in courgette jams, it was found that the citrus fruits used in their production had a beneficial effect on their characteristics (Table 5). The exception, however, was the taste of jams, which was rated the lowest, regardless of the sugar/xylitol version, with the addition of grapefruit due to the noticeable bitterness at 3.3 points and 2.9 points. Jams with the addition of lemon and lime received the highest marks for taste (5 points). According to consumers, the taste of jams with these fruits was sweet and sour, harmonized and refreshing. As confirmed by Ogori et al. (2021), the taste of products is a key factor influencing their acceptance and choice by the consumer. Therefore, the bitter taste of some of them is the main reason for their rejection (Bodakowska-Boczniewicz and Garncarek, 2016). The bitter taste of grapefruit is mainly due to naringin – a flavonoid glycoside, the content of which in grapefruit juice is about 470-900 μg/ml (Ribeiro and Ribeiro, 2008). In the case of the taste of jams with the addition of orange, the evaluators felt more intense sweetness and less pronounced sourness, hence the calculated average value for this distinguishing feature, regardless of the sugar/xylitol version, was 4.4 points. The taste of the control sample (without the addition of citrus fruits) was rated at 3.8 points for the version with sugar and 3.4 points for the version with xylitol. According to the evaluators, these jams were distinguished by a sweet and sour taste with a noticeable aftertaste of cooked courgette. In their opinion, the taste was not very harmonized. In the research conducted on pumpkin jams with the addition of various fruits by Kadzińska et al. (2014), the best taste among them was demonstrated by pumpkin-peach-orange and pumpkin-pineapple.

Depending on the content of citrus fruits, jams were distinguished by different colours – from light yellow (with the addition of lime and lemon), through orange (with the addition of orange) to pink-red (with the addition of grapefruit). According to the consumer assessment, the calculated average score for the colour of these products ranged from 4.3 points to 5.0 points. The highest scores for colour were given to jams with the addition of lime – 5 points for the version with sugar and 4.7 points for the version with xylitol. The colour of sugar-sweetened jams with the addition of orange (4.9 points) and xylitol-sweetened (4.6 points) was also highly rated. The colour of jams with the addition of grapefruit was rated slightly lower at the level of 4.3 points in both versions, which resulted in its high intensity, giving them a slight artificiality. The lowest average number of points, namely 3.7 (for the version with sugar) and 3.4 (for the version with xylitol) for colour was obtained by the jams (without the addition of citrus fruits) which were the control sample – their colour was not very intense, light cream with a slight yellow tint.

Table 5. Average values of the assessed characteristics of courgette jams with and without citrus fruits (control sample) in sugar/xylitol versions and their overall quality
Tabela 5. Wartości średnie ocenianych cech dżemów z cukinii z udziałem i bez udziału owoców cytrusowych (próba kontrolna) w wersjach cukier/ksylitol i ich jakość ogólna

Kind of jam/ Rodzaj dżemu	Organoleptic evaluation (1-5 points)/ Ocena organoleptyczna (1-5 pkt)					General acceptability (1-9 points)/ Ogólna akceptowalność (1-9 pkt)
	Sugar/ Cukier					
	Colour/ Barwa	Taste/ Smak	Flavour/ Zapach	Consistency/ Konsystencja	Overall quality/ Jakość ogólna	
	Weighting factors/ Współczynniki ważkości					
	0.2	0.3	0.3	0.2		
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	3.7	3.8	2.7	3.6	3.41	5.1
Courgette + orange/ Cukinia + pomarańcza	4.9	4.4	4.6	4.8	4.64	7.9
Courgette + lemon/ Cukinia + cytryna	4.6	5.0	4.7	4.8	4.79	8.7
Courgette + grapefruit/ Cukinia + grejpfrut	4.3	3.3	4.4	4.6	4.09	5.2
Courgette + lime/ Cukinia + limonka	5.0	5.0	5.0	4.8	4.96	8.9
	Xylitol/ Ksylitol					
Control sample (without the addition of fruit)/ Próba kontrolna (bez dodatku owocu)	3.4	3.4	3.2	3.7	3.40	5.0
Courgette + orange/ Cukinia + pomarańcza	4.6	4.4	4.4	4.9	4.54	7.7
Courgette + lemon/ Cukinia + cytryna	4.3	5.0	4.7	4.7	4.71	8.4
Courgette + grapefruit/ Cukinia + grejpfrut	4.3	2.9	4.6	4.7	4.05	5.0
Courgette + lime/ Cukinia + limonka	4.7	5.0	5.0	4.9	4.92	8.8

Source/Źródło: own study/opracowanie własne.

The evaluated jams in terms of smell with the addition of citrus fruits received high scores (from 4.4 to 5.0), which means that they had an aromatic, intense and harmonized aroma. The highest mark for the smell (5.0 points) in both sugar/ xylitol versions was awarded to the jam with the addition of lime in the consumer

assessment. The smell of jams with its addition was assessed as intensely citrus, very pleasant and aromatic.

Consumers also recognized the beneficial effect of the addition of citrus fruits on the consistency of courgette jams. The scores awarded to the products for this distinguishing feature ranged from 4.6 points to 4.9 points. The lowest score was given to the consistency of jams made from courgette alone (without the addition of fruit), in both versions: with sugar at 3.6 points and with xylitol at 3.7 points. All jams showed a fairly stable and compact gel structure. In jams with the addition of citrus fruit, the perceptibility of fruit particles also had a beneficial effect on their consistency. In contrast to them, the consistency of jams made from courgette alone (without the addition of fruit) was too smooth, and uniform, which was not necessarily to the satisfaction of the evaluators.

On the basis of the calculated overall quality, none of the jams with the addition of citrus fruits received a rating lower than 4.05, which proves their high quality (Table 5). Among the citrus fruits used, the addition of lime best profiled the quality of the final product, regardless of the sugar/xylitol version, at the level of 4.96 and 4.92. An equally high overall quality (4.79 and 4.71) was noted for jams with the addition of lemon and orange (4.64 and 4.54), while jams with the addition of grapefruit received a slightly lower score for quality at the level of 4.09 and 4.05. The result was a low score for the taste discriminant, in which a distinct bitterness was felt, which is characteristic of grapefruit. For comparison, the general quality of jams made from courgetti alone (without the addition of citrus fruits) was rated by consumers as satisfactory.

Among the five tested jams, the highest acceptability of 7.7 to 8.9 was found in courgette-lime, courgette-lemon and courgette-orange jams, and the lowest acceptability was in courgette-grapefruit and courgette jams (without the addition of fruit).

5. Conclusions

1. The development of jams based on courgettes (zucchini) alone gives a lower quality product than using the addition of citrus fruits.
2. The citrus fruits used turn out to be a technologically effective addition in profiling the sensory properties of courgette jams, with the exception of grapefruit due to its bitterness.
3. Citrus fruits improve the nutritional value of the analysed courgette jams and seem to be a suitable raw material for their enrichment.
4. The complete replacement of sugar in courgette-fruit jams with xylitol makes it possible to obtain products with equally well-preserved sensory properties, which may constitute the so-called special purpose food.
5. All the assessed jams met the requirements in terms of the designated physicochemical characteristics such as acidity, pH and total extract.

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