PAPER

SENSORY OPTIMISATION IN NEW FOOD PRODUCT DEVELOPMENT: A CASE STUDY OF POLISH APPLE JUICE

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ABSTRACT

A large variety of juices representing a wide range of sensory profiles can be found on the market. Nevertheless, their manufacturers may not fully recognise the needs and demands of consumers. The aim of the study was to verify a new strategy for consumer product testing using apple juice as an example. The material comprised of 14 apple juices. The sensory analysis was carried out by a team of 130 assessors. The impact of individual physicochemical parameters on the results of the juice sensory assessment was tested with the use of generalised additive models (GAM). The results of the research indicate that the most preferred apple juice is characterised by a balanced sweet and sour taste, low density as well as the colour described by a compromise between the high value of L* and low values of a* and b* parameters and a relatively low price. After the analysis of the map of preferences and its comparison with the results of the sensory assessment, it can be concluded that the products tested do not fully meet the consumer expectations. The research adds new insight into knowledge on new food product development. It shows that by examining the sensory desirability of products available on the market and by employing the GAM analysis the characteristics of the most appreciated product can be determined.

Keywords: new food product development, apple juice, new product, consumer preference

1. INTRODUCTION

Along with the technical and technological progress in the world, consumer needs and expectations are likewise gradually changing. For this reason, from the point of view of food industry companies, it is very important to continuously develop concepts for new products. In this way, they can quickly adapt to new market conditions and meet the needs of their customers. The consumer is more often seen not only as a user of products, but as a decision-maker on the market, and the traditional view of the consumer buying behaviour being associated with the assumptions of economic rationality has been replaced by behavioural theories of choice and preferences (HALAGARDA, 2017; SAGAN 2011).

Rising competition and customer expectations have led juice producers to develop a range of technologies in order to improve production and make their goods more attractive (KUDEŁKA and GŁUSZEK, 2014). As a result, a large variety of juices can be found on the market: raw and not from concentrate, both cloudy and clear, as well as juices from concentrate, or traditional and organic products (KUDEŁKA and GŁUSZEK, 2014). In this respect, products that are commercially available represent a wide range of sensory profiles. Nevertheless, their manufacturers may not fully recognize the needs and demands of consumers (MOSKOWITZ *et al*., 2006).

According to Fuller (2011), the results of the evaluations of the products available on the market should be used as an inspiration when generating ideas for new products that better correspond to the changing needs and expectations of consumers. Cooper (2001) and Lord (2008) state that competitive products are a valuable source of ideas for new products. Based on competitive analysis, the data on the position of the product on the market and characteristics of products and the benefits they offer to customers as well as their weak and strong points can be determined (RUDDER, 2003). This in turn may allow to formulate the necessary criteria to be fulfilled by a newly developed product (COOPER, 2001).

It is, however, important to consider consumer needs at each stage of the product development or improvement process (VAN KLEEF *et al*., 2005; Bogue and Sorenson, 2008). Nevertheless, consumer tests are paramount in their early stages and in the assessment of the product before its commercialisation. Their execution involves significantly lower costs than those that may be incurred in connection with the failure of a new product (MALTZ and KOHLI, 1996). According to Mattsson and Helmersson (2007), the participation of consumers in the initial phase of the new food product development is one of the three factors determining market success.

The unsatisfied needs of consumers create opportunities for the development of new products (LORD, 2008). Fulfilling expectations, especially sensory ones, leads to consumer satisfaction and increases the likelihood of product’s marketability (GRUNERT, 2002). The obtained information may also reveal market niches. Products developed to fill these niches have greater chances of success. Moreover, if the consumer reports the demand for a particular food product, the risk of failure significantly decreases (ANDERSEN and MUNKSGAARD, 2009).

The choice of a particular method or a research tool is not a simple task. Despite the fact that the aim is to provide information that can be used to determine the parameters of the product and estimate the level of consumer satisfaction with the new product, the processes of data collection can differ and, accordingly, the respondents can articulate their needs and requirements in different ways. In addition, the purpose behind research is of high importance. The company's goals may involve, for example, an introduction of the product to existing markets or creation of new markets. More reliable research results are achieved when consumers can appeal to their experience with the products already

available on the market. The data achieved may provide information about the product benefits that are anticipated by consumers. However, if competitors fully recognize these anticipations, a reliance on such data may result in imitation products being developed (VAN KLEEF *et al*., 2005).
Physicochemical tests and/or descriptive analyses are used to characterise competitive products. Consequently, data on sensory characteristics of the products are compared with their physicochemical parameters, and the degree of their consumer acceptance. (MOSKOWITZ *et al*., 2006; MOSKOWITZ *et al*., 2008).
The aim of the study was to verify a new strategy for consumer product testing using apple juice as an example. To achieve this goal, the following hypothesis was set up: a comparison of the features desired by consumers with the results of physicochemical analyses constitutes valuable input data for the development process of a new product.

2. MATERIALS AND METHODS

2.1. Juice samples

The research material comprised of 14 apple juices, selected from those available on the Polish market, and divided into 3 groups. The first group was formed of five not form concentrate juices that were registered on the List of Traditional Products of the Polish Ministry of Agriculture and Rural Development. The second group comprised of six conventional not from concentrate juices, of which: four were obtained in the pressing process, one via squeezing, whereas the sixth product had no declaration of the manufacturing technology. The last group consisted of three juices made from concentrate and manufactured by leading Polish producers.
For the purpose of sensory analysis and in accordance with the literature guidelines (BARYŁKO-PIKIELNA and MATUSZEWSKA, 2009; ISO 6658:2005), the juice samples were coded using 3 random digits. Detailed data is shown in Table 1.

2.2. Sensory analysis

The desirability analysis of the apple juices was carried out by a team of 130 assessors - all regular consumers of the category. Consumer tests were conducted in a sensory laboratory that was designed in accordance with the ISO 8589:1988 Standard. Evaluations were performed under artificial daylight and at room temperature (controlled between 22 and 24°C) and with the use of recirculation air system. The consumers were given the 50 ml samples of the juices in glasses alongside plain water to prevent carryover of the taste of the former samples. A rest period of at least 30 seconds was scheduled between each sample test. Data were collected through self-administered questionnaires previously explained to consumers. The desirability of colour, consistency, palatability, sweet palatability, sour palatability and the whole product were determined with the use of 9-point hedonic scale and according to the ISO 11136:2014 Standard.
In the first stage the consumers were given the samples for evaluation without knowing the price. Additionally, both the internal (sensory attributes and physicochemical properties) and external (price) factors were taken into account in the assessment of the quality and desirability of the product (MENICHELLI *et al*., 2012). Therefore, in the second stage, the consumers were asked to verify their overall rating when given the price of the product they assessed.

Table 1. The coding and prices of juice samples.

No.	Juice	Price, [PLN/l]	Code
1	NFCJ – fresh, squeezed	10,00	251
2	FCJ	4,24	423
3	FCJ	3,79	513
4	NFCJ – cold pressed	2,65	426
5	FCJ	3,33	754
6	NFCJ – pressed	4,27	896
7	RNFCJ – cold pressed	7,40	712
8	RNFCJ – cold pressed	5,33	381
9	RNFCJ – pressed	6,30	219
10	NFCJ – pressed	5,00	101
11	NFCJ	3,50	411
12	RNFCJ – cold pressed	6,00	129
13	NFCJ – cold pressed	6,10	613
14	RNFCJ – cold pressed	11,77	147

RNFCJ - not-from-concentrate juice, registered on the list of traditional products of the Polish Ministry of Agriculture and Rural Development
NFCJ - not-from-concentrate juice
FCJ- juice from concentrate

2.3. Physicochemical analyses

Four juices from the same production batch that was later used in the consumer assessment were tested. All analyses were performed in triplicate for each juice sample. The analyses covered the following:

2.3.1 Density

The density expressed in grams per 100 mL and converted to kg/L was determined using the Pycnometer Method by measuring the mass of the determined sample volume at 20±0.5°C and equating it to the mass of the same volume of reference liquid (distilled water) 20±0.5°C (PN-EN 1131:1999).

2.3.2 Titratable acidity

Titratable acidity was determined using 25 mL of a sample. The solution was continuously stirred by a magnetic stirrer and titrated against standardized solution of 0.1 mol NaOH to the end point (pH 8.1) using Mettler Toledo MP225 Basic pH/mV/°C meter. The titratable acidity was expressed as mmol H^+/L and calculated according to the following equation:

$$C = \frac{1000 \times V_1 \times c}{V_0}$$

(where, V_0: the volume of the sample in mL; V_1: the volume of NaOH used for sample titration in mL; c: the exact concentration of NaOH in mol/L).
The titratable acidity was also converted to amount of an anhydrous citric acid (gram per 1000 mL) of juice with the use of the following equation:

$$C_{CA} = C \times 0.064$$

(where, C: titratable acidity in mmol H^+/L) (PN-EN 12147:2000).

2.3.3 Total sugars

For the determination of total sugars, 25 mL of the test sample was transferred to a flask of 250 mL. 25 mL of distilled water was added and the sample was deproteinized with Carrez I and II mixture. Then the sample was filtered through a paper filter. 25 mL of filtrate was taken into a 100 mL flask. Subsequently, an inversion was performed with the use of 25 mL of distilled water, 5 mL of concentrated HCl and in the temperature of 68-70°C. The sample was cooled, neutralized and the contents of the flask were filled up to 100 mL with distilled water. The resulting solution was used as a titrant against the mixture of Fehling I and II solutions (5 + 5 mL) with methylene blue as the end-of-reaction indicator. Based on the amount of used solution, the total sugars content in the test sample was determined (PN-90/A-75101/07).

2.3.4 Colour

The colour was mapped by measuring L* a* b* parameters in the CIEL*a*b* system (MCLAREN, 1976) with the use of Minolta CM-3500d spectrophotometer.

2.3.5 Sugars/acids ratio

Sugars/acids ratios were calculated according to the equation:

$$SAR = \frac{S}{A}$$

(where, SAR: sugar acids ratio; S: total sugars; A: titratable acidity expressed as an anhydrous citric acid).

2.4. Statistical analysis

The data obtained from the research were analysed with the use of R 3.2.2. statistical package supplied by R Foundation for Statistical Computing (R CORE TEAM, 2017). The impact of individual physicochemical parameters on the result of the juice sensory assessment was tested with the use of generalized additive models (GAM) (WOOD, 2017). Dimension reduction aimed at the implementation of the juices' preference map was made using the first two principal components. Juices were divided into groups using agglomerative hierarchical clustering (dendrogram) with a complete linkage and Euclidean distance as a measure of the juices similarity. Before the development of the dendrogram, the physicochemical parameters were standardised in order to have a mean of 0 and a standard deviation equal to 1. In this way each of the physicochemical parameters had the same contribution to the Euclidean distance between the two juices. All of the tests were conducted at a significance level of α=0.05.
In order to verify the degree of fulfilment of consumer expectations by traditional and conventional apple juices available on the Polish market, a preference map was developed. Each of the analysed juices was described by 8 parameters (colour parameters: L*, a*, b*,

density, sugar/acid ratio, content of sugars, titratable acidity and price). Due to the difficulties in constructing an 8-dimensional map, it was decided that a two-dimensional one would be developed. 8 parameters were transformed into 2 that best described the tested juices. For this purpose, the Principal component analysis (PCA) was used. Two components that explain most of the variance were selected. Due to the different scales of selected variables, they were all standardised.

3. RESULTS AND DISCUSSION

3.1. The results of sensory and physicochemical tests

Sensory evaluations are used when developing new products and improving the characteristics of the products available on the market. However, due to difficulties arising from the nature of the sensory evaluation they are unfortunately seldom used by small and medium sized food companies (CARBONELL-BARRACHINA, 2007). Instrumental methods certainly provide objective data, but because of sensory analyses more comprehensive knowledge about the characteristics of products perceived by the senses can be provided (MURRAY *et al.*, 2001; CARBONELL *et al.*, 2008).

The results of the sensory desirability assessment of apple juices are presented in Table 2. They prove that the chosen research material showed variability in respect of consumer preferences of selected apple juice characteristics. The highest ratings for colour were achieved by two juices from concentrate (coded 513 and 754), whereas the lowest ratings by traditional not-from-concentrate juices (coded 381 and 219). Consumers did not have any major objections to the consistency of the juice samples tested. They mostly appreciated the consistency of fresh juice (sample 251), traditional not-from-concentrate juices (sample 712) and juice from concentrate (sample 754). The apple juices samples received mostly high rates for palatability and sour palatability as well. Consumers were highly satisfied with two juices: fresh (coded 251) and from concentrate (coded 423). The lowest rank was given to traditional not-from-concentrate juice (sample 129). Similarly, sweet palatability was highly valued in most of the cases. Again the exception was sample 129. The highest ranks were given to fresh juice (sample 251), juice from concentrate (sample 423) and traditional not-from-concentrate juices (sample 712). Considering overall rating, three juices were most appreciated by consumers: fresh juice (coded 251) and two juices from concentrate (coded 423 and 513). The lowest rating was received by traditional not-from-concentrate juice (coded 129). Considering the price of juice in overall rating two traditional not-from-concentrate juices were barely acceptable by consumers (samples coded 129 and 147). The best ratings were achieved by two juices: fresh (coded 251) and from concentrate (coded 423). The results of overall sensory acceptability ratings are in most of the cases similar to those presented in the literature. Aguiar *et al*. (2012) obtained average ratings for consumer apple juices at the level of 5.5-6.0 points in a 9-point scale. Włodarska *et al*. (2016) received overall acceptance ratings ranging from 4.1.to 6.3 also in a 9-point scale. Lee *et al*. (2016) obtained significantly higher scores of the experienced quality of the coded samples of freshly squeezed apple juices compared to juices pasteurised with the use of different technological methods. Similarly in this study the fresh juice (sample 251) received the highest overall rating, when omitting its price. Therefore, the results of sensory analysis conducted in this study and similar tendencies presented in the literature prove proper selection of the research material.

Table 2. The results of the consumer sensory desirability assessment of 14 apple juices selected for testing.

Juice	Colour	Consistency	Palatability	Sweet palatability	Sour palatability	Overall rating	Overall rating including the price
	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$	$\bar{\chi}(S.D)$
251	5.54 (1.69)	6.46 (1.34)	6.92 (1.21)	6.92 (1.00)	6.23 (1.67)	6.77 (0.89)	5.23 (1.62)
423	5.38 (1.33)	5.62 (2.10)	5.92 (1.38)	5.92 (1.49)	6.46 (1.22)	6.08 (1.27)	6.92 (1.21)
513	7.38 (1.39)	5.92 (1.86)	5.54 (1.82)	5.92 (1.64)	5.85 (2.21)	6.00 (1.71)	6.38 (1.15)
426	5.31 (1.32)	5.46 (1.65)	4.85 (2.03)	5.08 (1.98)	4.77 (1.72)	5.15 (1.96)	5.85 (2.11)
754	7.31 (1.77)	6.23 (2.04)	4.46 (2.13)	4.77 (1.89)	5.31 (1.98)	5.31 (2.09)	5.54 (1.78)
896	6.23 (1.58)	5.38 (1.64)	5.38 (1.50)	5.54 (1.50)	5.77 (1.42)	5.85 (1.35)	5.31 (1.26)
712	6.08 (1.49)	6.46 (1.50)	5.23 (2.45)	6.23 (2.42)	5.54 (2.59)	5.77 (2.08)	4.85 (2.41)
381	3.15 (2.18)	5.38 (1.69)	5.38 (1.60)	4.31 (1.59)	4.85 (1.61)	4.69 (1.38)	3.62 (1.60)
219	3.69 (1.73)	5.46 (1.28)	4.00 (2.29)	4.92 (1.86)	4.62 (2.31)	4.08 (1.64)	4.00 (2.04)
101	5.00 (1.47)	6.15 (1.23)	4.77 (1.97)	5.08 (1.21)	4.46 (1.82)	5.15 (1.17)	4.69 (1.38)
411	5.08 (1.90)	6.46 (1.45)	4.00 (2.80)	5.38 (2.17)	4.54 (2.59)	4.62 (2.65)	5.46 (2.76)
129	5.85 (1.46)	4.62 (1.90)	2.31 (1.43)	2.85 (1.51)	3.00 (1.96)	2.62 (1.44)	2.77 (1.76)
613	5.00 (1.75)	5.38 (1.78)	4.15 (1.56)	5.31 (1.49)	4.54 (2.06)	4.54 (1.22)	4.15 (1.10)
147	4.62 (2.10)	5.00 (1.36)	3.92 (1.86)	4.62 (2.24)	4.08 (1.54)	4.08 (1.64)	2.85 (1.61)

S.D. - standard deviation.

Table 3 contains the results of the physicochemical examinations used as a reference for the results of sensory desirability evaluations. They prove the typicality of the products used for the research (AIJN, 2007).

So far, there have only been a handful of studies on the quality of apple juices. RØDBOTTEN *et al*. (2009) and JAROS *et al*. (2009) showed that, as it is in the case of apples (DAILLANT-SPINNLER *et al*., 1996; JAEGER *et al*., 1998), for apple juices sweet and sour palatability are the most important parameters affecting consumer ratings. The sugar content in the product is a measure of the sweet palatability (MAGWAZA and OPARA 2015; BETT-GARBER *et al.,* 2014). The strong correlation between sour palatability and titratable acidity was also proved by various researchers (COROLLARO *et al*., 2014; BONANY *et al*., 2014; VAN DER MERWE *et al*., 2015).

JAROS *et al*. (2009), on the basis of principal component analysis for the instrumental data and Procrustes analysis for sensory data, demonstrated that the key attributes determining the consumer ratings of juices are: sweetness and acidity of the juice, as well as sweet/sour relation, the cloudiness of the juice and its colour.

In this study titratable acidity was chosen as a measure of sour palatability and the total sugar concentration as a measure of sweet palatability. Three juices tested were characterised by the highest total sugars content: two traditional juices (coded 712 and 147) and a pressed not-from-concentrate juice (coded 101). The lowest concentrations of total sugars were detected in two regional not-from-concentrate juices (coded 129 and 219). Two of the juices tested had the highest titratable acidity: juice from concentrate (coded 513) and not from concentrate juice (coded 411). The lowest acidity characterized two not-from-concentrate juices (coded 896 and 426).

The extract to acidity ratio is often used as a measure of the maturity of raw materials and palatability of processed fruits (MAGWAZA and OPARA, 2015). However, due to the importance of acidity and sweetness, in the case of apple juice, confirmed by RØDBOTTEN *et al*. (2009) and JAROS *et al*. (2009), the total sugars to acids expressed as an anhydrous citric acid ratio was chosen as a reference parameter for the overall palatability. The highest value of sugars/acids ratio characterised not-from-concentrate juice (coded 896), whereas the lowest regional not-from-concentrate juice (coded 219), juice from concentrate (coded 513) and not-from-concentrate juice (coded 411).

Table 3. The results of physicochemical examinations, chosen for comparison with the results of sensory analysis, of 14 apple juices selected for testing.

Juice	Colour			Consistency	Palatability	Sweet palatability	Sour palatability
	L*	a*	b*	Density, [kg/Ll]	Sugars/acids ratio	Total sugars, [g/Ll]	Titratable acidity, [mmol H+/Lmval]
	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$	$\overline{\chi}(S.D)$
251	69.49 (0.05)	1.91 (0.04)	26.46 (0.06)	1.043 (0.001)	25.01 (0.15)	95.22 (0.54)	59.5 (0.6)
423	93.98 (0.02)	-1.03 (0.02)	24.64 (0.03)	1.046 (0.001)	23.99 (0.12)	101.31 (0.49)	66.0 (0.0)
513	88.09 (0.05)	2.56 (0.02)	40.84 (0.01)	1.046 (0.001)	18.81 (0.16)	100.495 (0.22)	83.5 (0.4)
426	41.68 (0.30)	12.71 (0.15)	49.37 (0.12)	1.049 (0.001)	42.81 (0.73)	109.596 (0.73)	40.0 (0.4)
754	93.56(0.03)	-0.89 (0.01)	26.74 (0.05)	1.048 (0.001)	22.49 (0.18)	105.091 (0.83)	73.0 (0.6)
896	50.92 (0.22)	11.65 (0.23)	52.42 (0.15)	1.048 (0.001)	57.37 (0.72)	104.65 (0.65)	28.5 (0.8)
712	91.19 (0.13)	-0.59 (0.05)	23.64 (0.09)	1.052 (0.000)	30.09 (0.58)	117.495 (0.50)	61.0 (0.4)
381	58.74 (0.04)	7.20 (0.01)	34.02 (0.04)	1.050 (0.001)	25.49 (0.14)	103.61 (0.24)	63.5 (0.4)
219	55.34 (0.10)	5.64 (0.10)	26.10 (0.38)	1.045 (0.001)	16.76 (0.03)	81.51 (0.15)	76.0 (0.4)
101	58.73 (0.13)	7.79 (0.03)	36.62 (0.06)	1.048 (0.001)	29.01 (0.39)	115.10 (0.33)	62.0 (0.0)
411	58.59 (0.04)	3.96 (0.02)	37.14 (0.01)	1.047 (0.000)	19.08 (0.01)	98.32 (0.57)	80.5 (0.6)
129	87.13 (0.17)	-0.50 (0.05)	29.26 (0.16)	1.105 (0.001)	23.51 (0.27)	77.50 (0.23)	51.5 (0.8)
613	54.91 (0.11)	7.40 (0.10)	32.31 (0.33)	1.049 (0.001)	33.62 (0.08)	101.13 (0.23)	47.0 (0.4)
147	57.34 (0.18)	10.88 (0.05)	44.34 (0.03)	1.112 (0.001)	33.39 (0.21)	118.61 (0.56)	55.5 (0.4)

S.D. - standard deviation.

The density was selected as a measure of juice consistency. The tested apple juice samples showed similar density. The exceptions were two regional not-from-concentrate juices (coded 147 and 129), which had the highest densities.
The L* a* b* parameters mapped the colour of the apple juices tested. The highest value of L* parameter and therefore the highest lightness characterised two juices from concentrate (coded 423 and 754) and one traditional not-from-concentrate juice (coded 712). Sample 426 (not-from-concentrate juice) had the lowest value of this parameter among all of the tested products. This sample on the other hand, had the highest values of the a* parameter (the highest share of green shade). The lowest values of a* parameter characterised juices from concentrate (coded 423 and 754). Samples coded 896 and 426 (not-from-concentrate juices) had the highest values of b* parameter indicating yellow colour saturation.
Due to the fact that the composition of juice aroma is influenced by many chemical substances (mainly esters, C6 alcohols and aldehydes) (STANGL and ZIEGLER, 2014) research concerning this issue was omitted. Nevertheless, an independent project on the subject is planned.

3.2. Comparison of apple juices: similarities

To check the similarity of the analysed samples of juices, a hierarchical cluster analysis was performed. The physicochemical parameters, which constituted a reference point for the results of the desirability evaluations, and the prices of the analysed juices were considered. The results were compared with the results of the sensory assessments (Fig. 1).

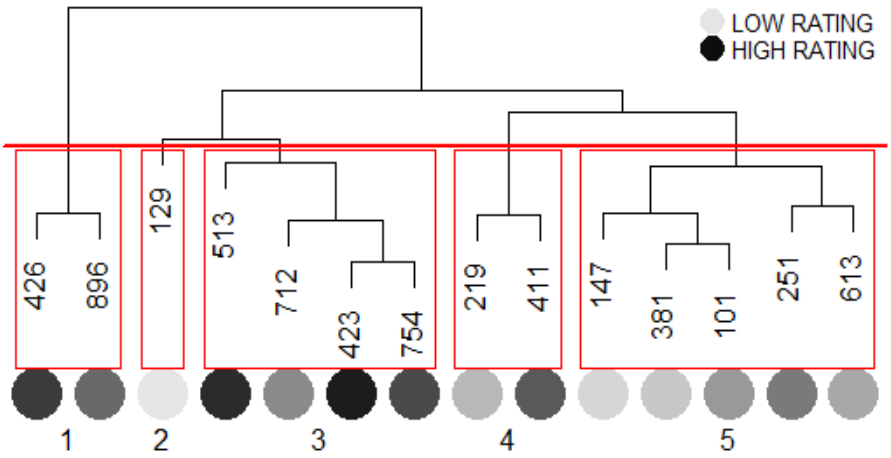

Figure 1. Clusters separated for the analysed samples of apple juice.

On the basis of the dendrogram, five product clusters were distinguished. The juices of clusters: 1 and 3 were characterised by high consumer desirability. Sample 129 shows a similarity to cluster 3 in terms of its physicochemical properties. Despite the preferred characteristics of the product, it received a low score in consumer test. This was a result of the poor palatability. The consumers' comments prove that the product was characterised by a peculiar insipid taste of negative associations, despite a rather good balance between the acid and sweet taste. However, volatile compounds were not analysed in the present study, and therefore, it was impossible to refer consumer opinions to specific physicochemical parameters. The last two clusters (4 and 5) comprised of products of medium to low consumer desirability.

3.3. An attempt to determine the parameters of the most desirable apple juice based on the parameters of juices available on the Polish market

The colour of the product significantly affects its perception. According to Spence (2015), there is a strong relationship between colour and perception of the type and intensity of flavour.

The chart (Fig. 2) presenting the relationship between the value of the colour parameter - L* and the consumer desirability is U-shaped. This means that the most preferred are the extreme values. The rating of the juices increases slightly faster on the right side of the graph. The ideal value of the L* parameter for apple juice determined by the GAM method and based on the analysis of the research material was 93.89. Therefore, it was found that consumers mostly prefer light coloured apple juices. However, the left part of the chart indicates that there is a group of consumers who are in favour of a juice of lower lightness. This was also confirmed by the research of WŁODARSKA *et al*. (2016), in which a segment of consumers who prefer juices with low values o L* colour coordinate was identified.

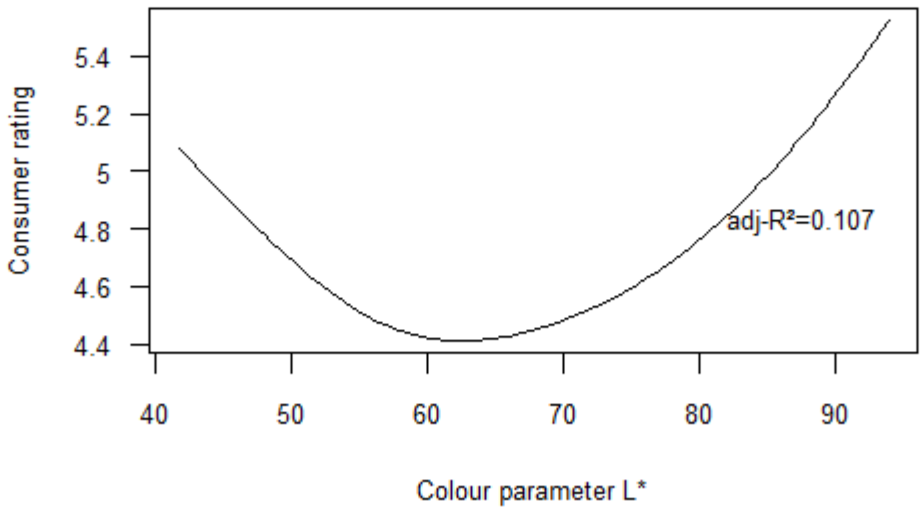

Figure 2. The relationship between the colour parameter L* and consumer desirability of the apple juice colour determined with the use of GAM model.

The relationship between the colour parameter - a* and the consumer desirability is linear (Fig. 3). The lower the value of a* parameter the higher the desirability of the product. Therefore it was found that consumers prefer apple juices of less perceptible greenish shade. The best value of the a* parameter for apple juice determined by the GAM method and based on the analysis of the research material was -1.03.

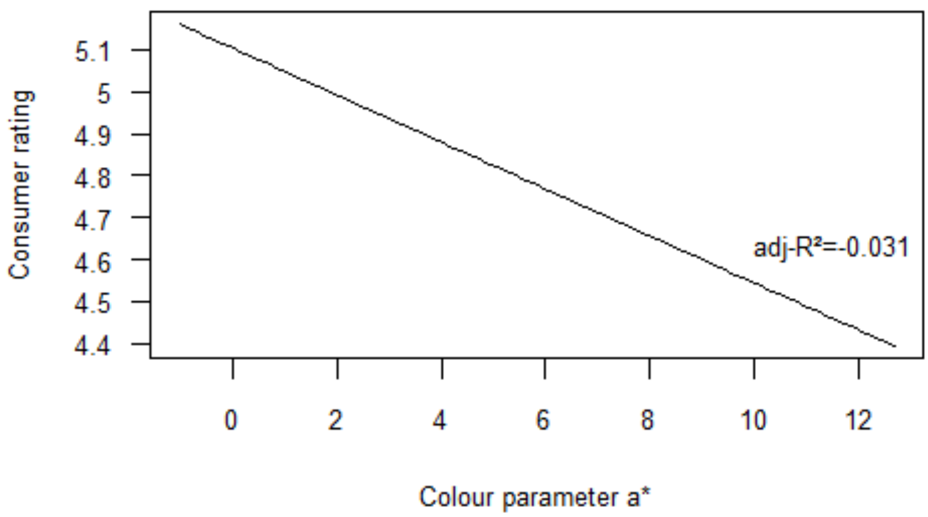

Figure 3. The relationship between the colour parameter a* and consumer desirability of the apple juice colour determined with the use of GAM model

The relationship between the value of the colour parameter b* and consumer desirability of the analysed apple juices is exponential (Fig. 4). The higher the value, the greater the consumer acceptance of the juice. The respondents preferred a more saturated colour, with a more pronounced share of yellow tone. The application of the GAM method made it possible to determine the most desirable value of the parameter b* within the range restricted by the parameters of the research material. It amounted to 52.42. The research results by CZARNOWSKA *et al*. (2014) also confirm that consumers prefer an intensive dark yellow colour of apple juice.

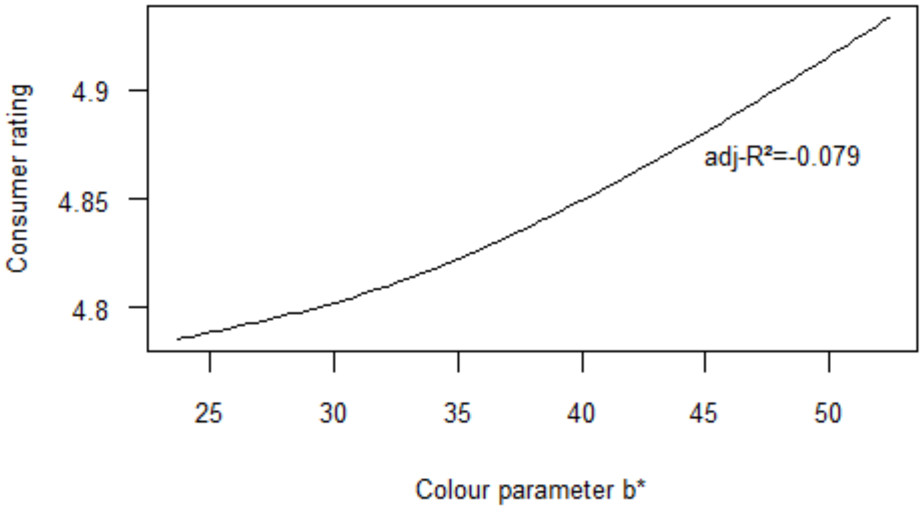

Figure 4. The relationship between the colour parameter b* and consumer desirability of the apple juice colour determined with the use of GAM model

According to the linear chart (Fig. 5), showing the relationship between the density of apple juice and its consumer desirability, the lower the density of apple juice, the more the beverage is favoured by consumers. Application of the GAM method made it possible to determine the most appropriate density - 1.043 kg/L. It was the lowest density among the identified values. Therefore, it can be stated that consumers prefer clear juices. This conclusion is consistent with the data presented in the 2014 report of the European Fruit Juice Association. According to it, 365 out of the 673 million litres of juices drunk by Poles in 2013 were made on the basis of concentrate (ANONYMOUS, 2014). The not-from-concentrate juices are not clarified by Polish producers so as not to lower their nutritional value. The research by CZARNOWSKA *et al*. (2014) also confirms preferences for clear juices. On the other hand, WŁODARSKA *et al*. (2016) recognized consumer segment which showed preference for juices of higher density identified with cloudy juices which are believed to have greater health benefits.
The relationship between the sugar/acid ratio and consumer desirability is linear (Fig. 6). The higher the ratio, limited by the characteristics of the analysed samples, the better the rating the juice received. The most preferred value of sugar/acid ratio was 57.37. JAROS *et al*. (2009) noticed that, when considering cloudy juices, the most preferred products had low sugar/acid ratio. They, however, indicated that there is an optimum of this ratio. Therefore, in the range limited by samples analysed in this study the preferences may be rising with the increasing sugar/acid ratio.

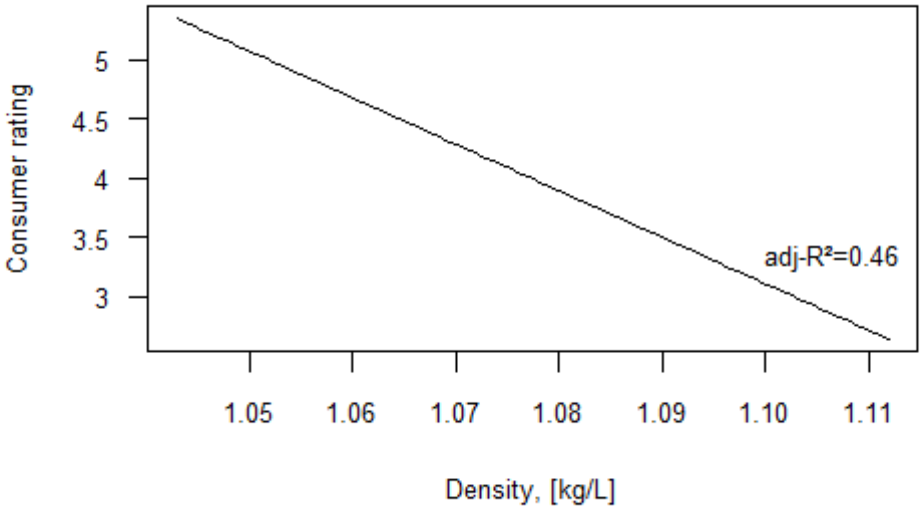

Figure 5. The relationship between density and consumer desirability of the apple juice consistency determined with the use of GAM model

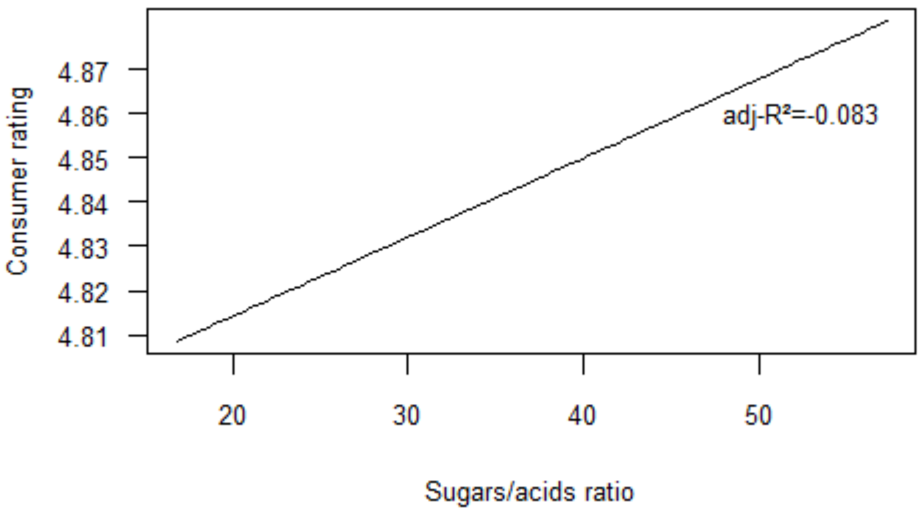

Figure 6. The relationship between sugars/acids ratio and consumer desirability of the apple juice palatability determined with the use of GAM model

According to research by JAROS *et al*. (2009), the majority of the surveyed consumers preferred the juice, which was more acidic and less sweet. However, their research also demonstrated the existence of a large group of consumers who prefer less acidic, sweeter juices. Similarly, RØDBOTTEN *et al*. (2009) showed variability of apple juice acidity preference between analysed consumer segments. This is in accordance with the results of this study, showing that the relationship (Fig. 7) between the titratable acidity and the consumer desirability of apple juice is complex. The ideal acidity for apple juice, determined in this research with the use of the GAM model based on the analysis of the research material, was 83.5 mmol H^+/L.

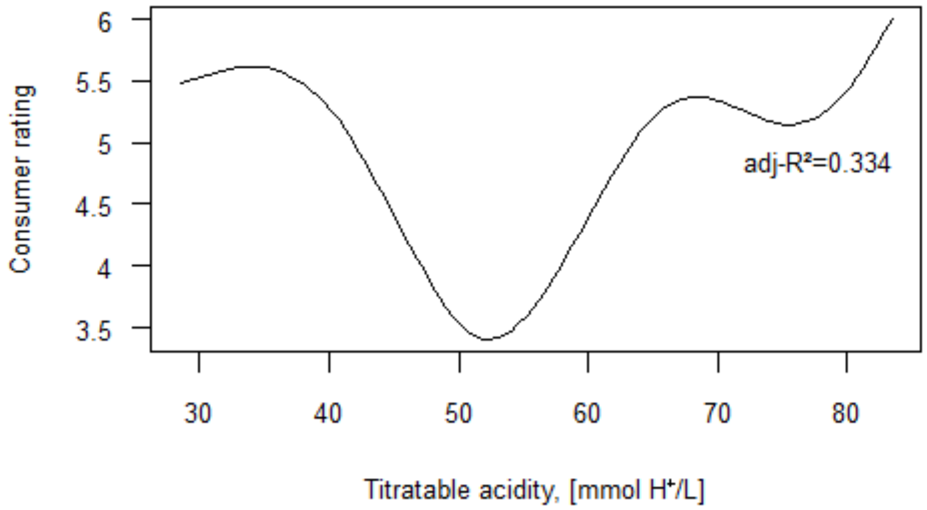

Figure 7. The relationship between titratable acidity and consumer desirability of sour palatability of apple juice determined with the use of GAM model

The chart (Fig. 8) presenting the relationship between the sugar content and the consumer desirability is in the form of an inverted U. The respondents, to a certain degree, prefer the sweet taste of juice. In the present study the limit was the sugar content of 100.83 g/l of juice. This is in accordance with JAROS *et al*. (2009) findings. In their research a correlation between consumer ratings and sweet palatability was found. They noticed that there is a sweetness intensity level limiting acceptance of an apple juice. Similarly, RØDBOTTEN *et al*. (2009), showed consumer preference for apple juices of a high sugar content, noticing that there might be an upper limit of sweetness.

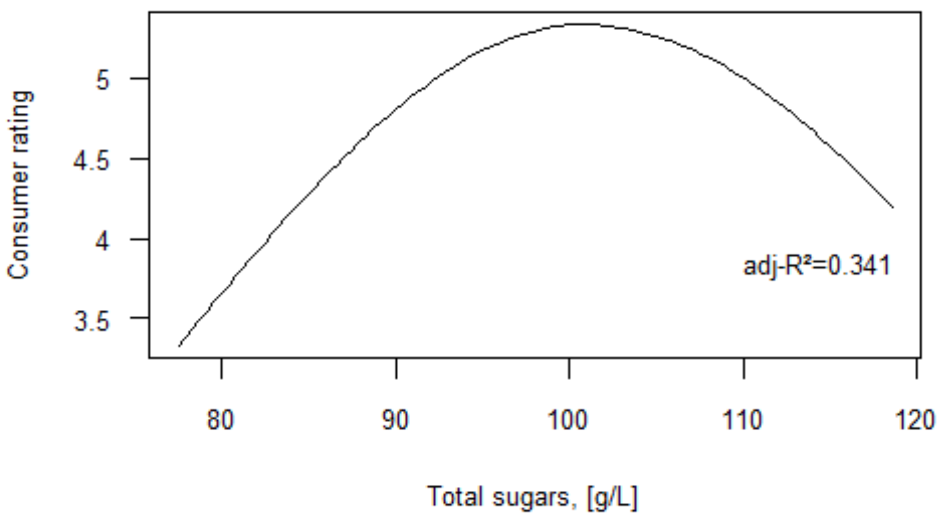

Figure 8. The relationship between sugar content and consumer desirability of sweet palatability of apple juice determined with the use of GAM model.

The relationship between the price of juice and its consumer desirability is non-linear (Fig. 9). Some respondents, most likely, identify the high quality of juice with its high price. However, at a given quality level, below which none of the tested products were found, products with lower prices are generally preferred. These findings are in accordance with the results of SHIRAI (2015) research. On the basis of the GAM analysis, it was determined that most respondents prefer the lowest price of the presented alternatives - 2.65 PLN/l juice.

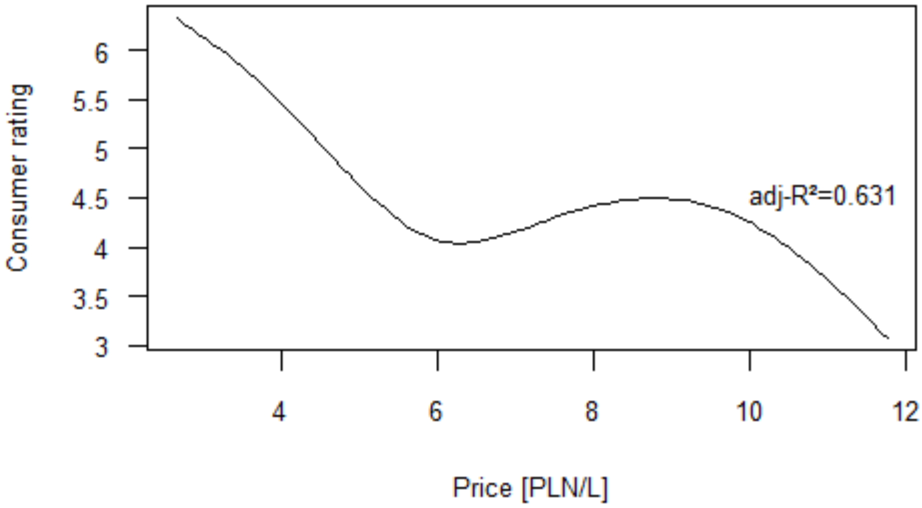

Figure 9. The relationship between the price and consumer desirability of apple juice determined with the use of GAM model.

Based on the results of the GAM analysis on 14 samples of apple juices available on the Polish market it can be concluded that the products most preferred by the respondents should have the following colour parameters: L*=93.98, a*=-1.03, b*=52.42, density of 1.043 kg/L, sugar content equal to 100,827 g/L, titratable acidity of 83.5 mmol H^+/L, sugar/acid ratio equal to 57.37 and the price of 2.65 PLN/L or less.

3.4. The preference map of apple juices available on the Polish market, with consideration of the ideal juice concept

Two principal components determined by PCA explain 66.25% of the variance of the whole data set, thus the obtained 2-dimensional map uses 66.25% of the information contained in the 8 original parameters. The exact patterns of the components were as follows:

- first component:

0.4·L* - 0.48·a* - 0.44·b* - 0.06·density - 0.45·sugar/acid ratio - 0.22· sugar content + 0.4·titratable acidity - 0.04·price

- second component:

0.04·L* - 0.01·a* - 0.12·b* + 0.69·density - 0.08·sugars/acids ratio - 0.03·sugar content - 0.1·titratable acidity + 0.1·price

Based on the determined pattern it can be stated that:

- the high values of the first component result mainly from the high titratable acidity and high values of the L* parameter and low of a* and b* parameters as well as low values of sugars/acids ratio;
- the high values of the second component are primarily related to high density and high price.

The values of the two components, calculated for each tested apple juice and the juice of the parameters most desired by the respondents are shown on the preference map (Fig. 10).

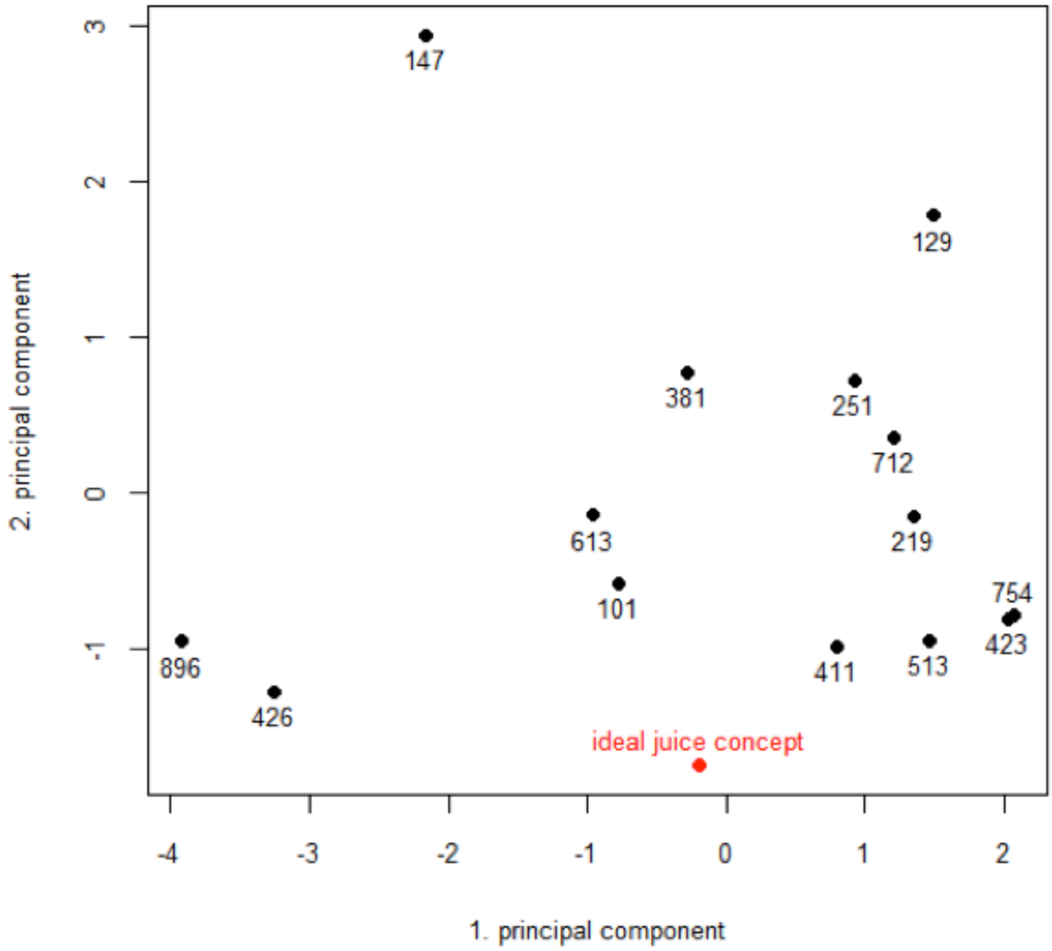

Figure 10. A preference map for the analysed 14 apple juice samples, showing location of ideal juice concept among tested products.

It was determined that the juice with the parameters most preferred by the consumers has:
- a first component being close to 0. The equation determining the first component shows a positive contribution of colour parameter L* and titratable acidity as well as negative contribution of a* and b* colour parameters and sugar/acid ratio. Therefore, the optimal juice parameters are a compromise between parameters of positive and negative contribution.
- low second component, and thus low density and low price.

The significance of the taste of the juice and its price is also confirmed by the results of the survey conducted by UCHEREK (2011). According KRAUS and POPEK (2013), the taste plays a pivotal role in the perception of food products by consumers.

When comparing the preference map with the results of the consumer desirability evaluation it can be concluded that the most appreciated apple juices have a low value of the second main component. Nevertheless, none of the analysed juices has a value of the first principal component at a level close to 0. This leads to the conclusion that the examined products do not fully meet the expectations of consumers. However, the apple juices coded 411, 513 and 101 have the values of the parameters closest to the parameters of ideal juice concept among tested samples. Juices 411 and 513 are characterized by low sugars/acids ratio, average total sugars content and high titratable acidity as well as moderate values of L* colour parameter. Sample 101 has moderate sugars/acids ratio and titratable acidity as well as high total sugars content and high value of L* colour parameter.

4. CONCLUSIONS

The results of the research confirmed the diversity of sensory characteristics of apple juices available on the market in Poland, as well as the typicality of physicochemical parameters of the analysed products. Agglomerative hierarchical clustering allowed to distinguish five groups of products, of which two where highly preferred by consumers. Thanks to GAM analysis dependences between the analysed physicochemical parameters of juices and their consumer ratings were identified. It was shown that: the relationship between the value of the colour parameter - L* and the consumer desirability is U-shaped, the relationships between the colour parameter - a* and the consumer desirability as well as density and the consumer desirability are inversely proportional and linear, the relationship between the value of the colour parameter - b* and consumer desirability is exponential, the relationship between the sugar/acid ratio and consumer desirability is proportional and linear, the relationships between the titratable acidity and the consumer desirability as well as between the price of juice and its consumer desirability are complex, whereas the relationship between the sugar content and the consumer desirability is in the form of an inverted U. On the basis of GAM analysis it was also shown that in the range of variability conditioned by the physicochemical parameters of the research material the ideal juice concept should be characterized by the colour identified by the following coordinates: L*=93.98, a*=-1.03, b*=52.42, density of 1.043 kg/L, sugar content equal to 100,827 g/L, titratable acidity of 83.5 mmol H^+/L, sugar/acid ratio equal to 57.37 and the price of 2.65 PLN/L or less. The results of PCA analysis allowed to indicate that the most preferred apple juice is characterized by a balanced sweet and sour taste, low density and a relatively low price as well as the colour described by the compromise between high value of the L* parameter and low values of the a* and b* parameters. After the analysis of the preference map and its comparison with the results of the sensory desirability assessment, it may be also concluded that the products tested do not fully meet consumer expectations. Therefore, a newly developed product that would meet consumer requirements stands a good chance of being successful on the market.

In this way it was shown that the comparison of the product features desired by consumers with its physicochemical parameters constitutes valuable input data that can be used during the product development process. Therefore, the set hypothesis was positively verified.

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