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EFFECT OF DIFFERENT TEA EXTRACTS ON THE PHYSICOCHEMICAL AND SENSORY PARAMETERS OF STIRRED PROBIOTIC YOGHURTS

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ABSTRACT

Background. In yoghurt production, additives and flavours are added after the fermentation process, but in the case of yoghurts with the addition of tea extracts all studies concern set-type yoghurts. For this reason, the aim of this study was to analyse the effect of green, black, red (Pu-erh) and white tea extracts addition on sensory characteristics, pH, viscosity and colour of stirred probiotic yoghurts stored for two weeks.
Methods. Skim milk powder (10% w/w), sucrose (4% w/w) and typical yoghurt cultures with the addition of *Lactobacillus acidophilus* LA-5 were applied for yoghurt manufacture. Then yoghurts were stirred and 4, 8, 12% black, red, green and white tea extracts were added. The samples were analysed after 1, 3, 7 and 14 days of storage at 5ºC. Instrumental colour ($L^*a^*b^*$) determination, rheological measurements and sensory evaluation were carried out.
Results. The pH analysis of the final yoghurt samples showed that the type and quantity of tea extract addition had little effect. Apparent viscosity was affected by 12% addition of tea extracts but not by storage time. The instrumental analysis of the colour confirmed the visual assessment. Sensory evaluation revealed that yoghurts with the addition of green tea extract were the most accepted. The addition of extracts made of red, black and white tea resulted in lower values of all the sensory characteristics tested.
Conclusion. The stirring method can be applied to the production of probiotic yoghurts with various tea extracts. The acidity of the yoghurts was practically not affected by the addition of the infusion derived from the different types of tea. 4% addition of tea extract did not affect the viscosity of the yoghurts. The best sensory scores among tea yoghurts were obtained by yoghurt with 4% green tea addition.

Keywords: yoghurt, green tea, red tea, white tea, black tea, rheology

INTRODUCTION

Yoghurt is milk fermented by *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. Besides regular yoghurt, Codex Alimentarius contains the definition of alternate culture yoghurt that combines cultures of *Streptococcus thermophilus* and any *Lactobacillus* species (Codex Alimentarius, 2011). However, many yoghurts available on the market contain additional probiotic bacteria

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from the *Bifidobacterium* genus (Shah, 2011). From a technological perspective, there are different types of yoghurts: incubated in packages (set), incubated in tanks and pumped to the packages (stirred) and those stirred with a more sheared structure that are often diluted with fruit concentrate (drinkable) (Bylund, 1995; Loveday et al., 2013).

The popularity of yoghurt results from its specific taste as well as its nutritional value. Consumption of yoghurt can influence the immune system and consequently decrease the risk of some diseases such as cancer, gastrointestinal disorders and allergic symptoms (Shokery et al., 2017). Moreover, yoghurt is a source of high-quality protein, vitamins and mineral components (Gahruie et al., 2015).

Infusion of tea leaves (*Camellia sinensis*) is one of the most widely consumed beverages in the world, mainly because of its aromatic and flavour benefits. Tea infusions are a source of antioxidants, which can reduce the risk of cancer and cardio-vascular diseases (Michalak-Majewska, 2011). There are four main types of tea: natural (white, green), partly fermented (oolong or blue), post-fermented (Pu-erh or red) and fully fermented (black) (Mo et al., 2008; Tong, 2005). The nutritional merits of tea in conjunction with the tendency of the consumers to find new flavour perceptions in yoghurt products have caused the emergence of new tea-flavoured yoghurts, as well as researchers' increased interest in developing yoghurts with the addition of tea extracts (Granato et al., 2018). To date, yoghurts with the addition of mainly green tea extracts or its lyophilisates have been studied (Amirdivani and Baba, 2013, 2015; Dönmez et al., 2017; Jaziri et al., 2009; Muniandy et al., 2016; Najgebauer-Lejko et al., 2014; Shokery et al., 2017), although some studies concerned the addition of black (Jaziri et al., 2009; Muniandy et al., 2016), white (Muniandy et al., 2016) and also red (Pu-erh) tea (Najgebauer-Lejko et al., 2014). The most important finding from the abovementioned reports is that the addition of green tea extracts to milk before fermentation positively affects the growth of yoghurt microorganisms during fermentation (Amirdivani and Baba, 2015). Furthermore, the storage period does not change the microbial count of streptococci and lactobacilli in comparison to plain yoghurt (Jaziri et al., 2009). Additionally, the level of polyphenols present in tea yoghurts does not usually change significantly during the storage time and the antioxidant properties of yoghurts are significantly high, especially when compared to plain yoghurt (Amirdivani and Baba, 2015; Muniandy et al., 2016).

Sensory analysis of yoghurts with the addition of green tea did not reveal unequivocal results. Shokery et al. (2017) reported that yoghurt without additives shows better sensory parameters than that with green tea, although the opposite results were obtained by Amirdivani and Baba (2013). Many authors have carried out rheological and textural analyses. Shokery et al. (2017) reported no significant changes in viscosity and firmness between plain and green tea yoghurt. Dönmez et al. (2017), when analysing 0.01, 0.02, 1 and 2% addition of green tea powder, recorded unequivocal rheological results during 14 days of storage. Amirdivani and Baba (2013) showed better scores for texture in green tea yoghurts than in the control. These results were confirmed by Najgebauer-Lejko et al. (2014), who showed that the index of viscosity, as well as cohesiveness for green tea and Pu-her yoghurts were significantly higher than for the control, although analysis of consistency, as an outcome of back extrusion tests, showed no difference.

To the best of our knowledge, all articles available in the databases describe set-type yoghurts with the addition of tea extracts. In a typical yoghurt production process, additives and flavours are added after the fermentation process (Bylund, 1995; Loveday et al., 2013), and nowadays most of the yoghurts available on the market are of the stirred and drinkable type. In the case of a set-type yoghurt, the addition of tea extracts did not cause such a deterioration in quality as to be rejected. The question remains how the addition of such extracts will affect the quality of processed stirred yoghurts. Moreover, as far as we know, until now no reports have compared the sensory and rheological evaluation of processed stirred yoghurts fortified with four different tea extracts. Due to this, the aim of this study was to analyse the effect of green, black, red and white tea extract addition on sensory characteristics, pH, viscosity and colour of stirred probiotic yoghurts stored for two weeks.

MATERIAL AND METHODS

Materials

Skim milk powder (SMP) (SM Gostyń, Gostyń, Poland), sucrose (Polski Cukier, Toruń, Poland), black tea (Yunnan), green tea (Roger Sp. z o.o., Łódź, Poland), white tea (Teekanne Kokotów, Poland) and red (Pu-erh) tea (BiFIX, Tuszyn, Poland) were purchased from a local supermarket. All the teas used in this study were leaf teas. The protein, lactose, and fat contents in SMP were 35.7, 51.2, and 1.3%, respectively (manufacturer's data). DVS ABT-1 culture (*Lactobacillus acidophilus* LA-5, *Bifidobacterium animalis* subsp. *lactis* BB-12, *Streptococcus thermophilus TH-4*) was donated by Chr. Hansen (Poland).

Preparation of tea extracts

Samples of 25 g dry tea leaves were infused in static in 210 ml of distilled hot water (100°C for black tea, 95°C for red tea, 85°C for green and white tea). The temperatures used were based on the manufacturer's recommendations. After natural cooling for one hour, the infusions, still containing tea leaves, were covered with aluminium foil and stored at ambient temperature for about 20 hours, until they were applied to yoghurt after separating tea leaves on a sieve.

Yoghurt manufacture

The procedure was very similar to that described by Glibowski and Rybak (2016). Briefly, milk powder (10% w/w) and sucrose (4% w/w) were dispersed in distillate water at 23ºC with moderate mixing using a magnetic stirrer. The dispersions were stirred and homogenized in a laboratory homogenizer H 500 (Pol-EkoAparatura, Wodzisław Śląski, Poland). Afterwards, the solutions were poured into flasks, and the flasks were sealed with aluminium foil and pasteurised in a water bath at 80ºC for 30 min. Subsequently, the solutions were cooled in tap water to 45ºC and DVS ABT-1 culture (*Lactobacillus acidophilus* La-5, *Bifidobacterium* BB-12, *Streptococcus thermophiles*) was added at a level of 0.015% (w/w). After that, the solutions in flasks were sealed with aluminium foil, incubated for 5 and stored for 19 hours at 45 and 5ºC, respectively, in a thermostatic cabinet. Then the yoghurts were stirred with a laboratory spoon (Glibowski and Rybak, 2016) and 4, 8, 12% tea liquid extracts (infusions without tea leaves) were added. Next, yoghurts were stirred again, poured into plastic cylindrical containers with a 35 mm inner diameter and the lids were twisted on to prevent evaporation. The samples were analysed after 1, 3, 7 and 14 days of storage at 5ºC. Sensory analysis was carried out after 48 hours of storage after production. The yoghurts were manufactured in three independent trials.

pH measurement

The pH was measured using aCP-401 pH-meter (Elmetron Sp. J., Zabrze, Poland).

Rheometry

Rheological measurements were conducted using a Brookfield DV-II+ rheometer (Brookfield Engineering Laboratories, Middleboro, USA) equipped with an S21 spindle. Apparent viscosity was measured at 9.3 s^{-1} shear rate for 120 s. For the analytical purposes, the average value was calculated from the 90th, 105th and 120th second of the measurement (Glibowski et al., 2008). All rheological data were collected and calculated by Wingather V1.0 (Brookfield Engineering Laboratories, Middleboro, USA).

Instrumental colour ($L^*a^*b^*$) determination

The samples were evaluated for instrumental colour using a spectrophotometer (Color Premiere 8200; X--Rite Inc., Grand Rapids, MI, USA). The analysis was carried out according to Karwowska and Kononiuk's method (2018) with slight modifications. In brief, the instrumental conditions were: 25.4-mm port size, D65 illuminant and 10° standard observer. Prior to colour determination, the samples were wrapped in an air-permeable polyethylene film. Each time before use, the colorimeter was standardized against a white ceramic calibration tile wrapped in the same polyethylene film used for the samples. Colour coordinates were determined by applying the CIELAB system. The results were expressed as L^* (lightness/darkness), a^* (red/green) and b^* (yellow/blue).

Sensory evaluation

Sensory evaluation was conducted using 16 semi-trained panellists (graduate students of our university). The panellists (non-smoking, 10 women and 6 men, aged 23 to 25 yr old) examined the samples by tasting and recording their perceptions using nine-point grade scores (1 – extremely dislike, 9 – extremely like). Analysis of the 4 samples was performed in daylight, during which 20 g of each sample was served in containers coded with random 3-digit numbers at a temperature of approximately 12°C, and in a monadic manner (Janiaski et al., 2016). They examined colour, flavour, aroma, sweetness, sourness, consistency and general acceptance (Bączkowicz et al., 2012; Gad et al., 2010).

Statistical analysis

The rheological and colour measurements were completed in three independent trials. Each analysis was performed in duplicate. All data were analysed by the Statistical Analysis System (SAS Enterprise Guide 3.0.3.414) using ANOVA procedure for analysis of variance and Student-Newman-Keuls t-test for ranking the means. In the case of sensory analysis, the mean values were taken from the grade scores recorded by the panellists.

RESULTS AND DISCUSSION

pH

Table 1 shows the pH value of the yoghurts after 3, 7 and 14 days of storage. The acidity of the yoghurts with the addition of various teas was similar and after three days of storage, the pH ranged from 4.67 to 4.74. Even 12% addition of tea did not drastically change the pH values. The time of storage significantly influenced ($P \leq 0.05$) the pH of the yoghurts. After 14 days of storage, the acidity significantly decreased, reaching a pH in the range of 4.84–5.04. The acidity values were slightly higher than those for typical yoghurt, i.e. pH 4.5 (Bylund, 1995). Dönmez et al. (2017) previously reported changes in the pH values of yoghurt with the addition of green tea powder similar to the results presented in this study. They also showed no significant differences between the concentration of additive and the yoghurt pH. Jaziri et al. (2009) recorded that storage time caused minor changes in the acidity value of yoghurt. Shokery et al. (2017), when analysing the impact of green tea addition to yoghurt, recorded a pH above 4.5 within 15 days of storage. Acidity is one of the indicators showing the microbiological activity of bacteria used for yoghurt fermentation. Previous reports on the production of yoghurt with the addition of tea have shown that the viability of yoghurt bacteria is better than in yoghurts without tea (Amirdivani and Baba, 2015). However, in the case of stirred-type yoghurt, in which the addition of tea extract takes place after fermentation, studies that showed no impact of storage time on the number of streptococci and lactobacilli are more important (Jaziri et al., 2009). We can therefore assume that the number of yoghurt bacteria has not changed. Further studies are needed to confirm these assumptions, because we used not only typical yoghurt bacteria but also probiotic bacteria in our research.

Table 1. pH of yoghurts as an effect of storage at 5°C

	Storage time, days		
	3	7	14
N	4.73^{l} ±0.01	4.87^{jk} ±0.01	4.84^{k} ±0.01
B4	4.69^{mno} ±0.01	4.92^{gh} ±0.01	4.94^{defg} ±0.01
B8	4.72^{lm} ±0.02	4.96^{cdef} ±0.01	5.01^{b} ±0.01
B12	4.74^{l} ±0.01	4.97^{cde} ±0.01	5.04^{a} ±0.01
R4	4.65^{p} ±0.02	4.90^{hij} ±0.01	4.87^{jk} ±0.01
R8	4.67^{op} ±0.01	4.93^{fgh} ±0.01	4.93^{fgh} ±0.01
R12	4.69^{mno} ±0.01	4.95^{defg} ±0.01	4.96^{cdef} ±0.01
G4	4.68^{op} ±0.02	4.89^{ij} ±0.01	4.87^{jk} ±0.01
G8	4.71^{lmn} ±0.01	4.93^{fgh} ±0.01	4.94^{efg} ±0.01
G12	4.69^{mno} ±0.01	4.94^{defg} ±0.01	4.98^{cd} ±0.01
W4	4.67^{op} ±0.01	4.91^{ghi} ±0.01	4.88^{j} ±0.01
W8	4.67^{op} ±0.01	4.94^{gfe} ±0.01	4.96^{cdef} ±0.01
W12	4.68^{no} ±0.01	4.96^{cfde} ±0.01	4.99^{bc} ±0.01

Data are presented as means ±standard deviation. Means with different superscript letters are significantly different, $p \leq 0.05$. N, B, R, G, W – represents plain yoghurt and yoghurts with black, red, green, white tea addition, respectively, 4, 8, 12 – percentage addition of tea extracts.

Apparent viscosity

The results of the apparent viscosity analysis are presented in Table 2. The addition of tea extracts to the yoghurts decreased their apparent viscosity. Since the

Table 2. Apparent viscosity of yoghurts as an effect of storage at 5°C, mPa·s

	Storage time, days		
	3	7	14
N	283^{bcde} ±3	335^{a} ±0	283^{bcde} ±3
B4	290^{bcd} ±34	273^{cdef} ±33	249^{defghij} ±32
B8	253^{cdefghi} ±34	214^{ghijklm} ±31	197^{jklmn} ±25
B12	222^{fghij} ±37	183^{klmn} ±28	156^{n} ±21
R4	259^{cdefgh} ±35	281^{bcde} ±41	254^{defghi} ±28
R8	231^{efghijk} ±31	243^{defghij} ±43	217^{ghijkl} ±21
R12	204^{ijklm} ±28	207^{hijklm} ±30	170^{lmn} ±19
G4	291^{bcd} ±40	263^{cdefg} ±31	250^{defghij} ±19
G8	253^{defghi} ±33	232^{efghijk} ±32	204^{ijklm} ±29
G12	201^{ijklm} ±28	221^{ghijk} ±29	167^{mn} ±21
W4	302^{abc} ±30	321^{ab} ±32	260^{cdefgh} ±28
W8	243^{defghij} ±27	282^{bcde} ±34	206^{ijklm} ±28
W12	218^{ghijkl} ±20	248^{efghij} ±36	182^{klmn} ±15

Data are presented as means ±standard deviation. Means with different superscript letters are significantly different, $p \leq 0.05$.

yoghurts that were tested were obtained by the stirring method and the addition of tea took place after yoghurt fermentation, the recorded decrease in viscosity seems obvious, especially at the 12% addition of extract. However, in most cases, we did not notice significant differences between 4 and 8% tea extract addition, nor with 8 and 12%. Such a difference was seen between 4 and 12% addition.

In most samples, the storage time did not significantly alter ($P \leq 0.05$) the apparent viscosity of yoghurts, suggesting that the addition of up to 12% of tea extracts is feasible in industrial practice. Although we recorded some decrease in apparent viscosity during storage, all the yoghurts analysed were of good quality throughout the storage period and revealed no syneresis (data not shown). These observations were partly confirmed by visual assessment (Fig. 1) and sensory analysis discussed later in the text. This indicates that the addition of tea extracts can be applied in the production of stirred yoghurts.

To the best of our knowledge, available literature contains only research concerning the rheological analysis of set-type yoghurts. Shokery et al. (2017) reported no significant differences in rheological properties of freshly made yoghurt with and without the addition of green tea extract, but observed a significant increase in viscosity after 15 days of storage. Similarly, Najgebauer-Lejko et al. (2014), in their studies, found an increase in the viscosity index of yoghurt with the addition of Pu-erh and green tea extracts in comparison to the control yoghurt, while Amirdivani and Baba (2015) recorded lower viscosity of yoghurt with the addition of tea, although the method used for yoghurt production is not clear. Additionally, they reported that the storage period had no significant effect on yoghurt viscosity.

Colour parameters

Colour analysis showed that the lightness of yoghurt without tea was the highest (Table 3). Increasing addition of tea extracts decreased the L^* values of yoghurts. The darkest yoghurts were made with the addition of black or red tea (Table 3, Fig. 1). The storage time increased the lightness of the control yoghurt and those with the addition of tea extracts. The similar tendency with L^* parameter was recorded by Najgebauer-Lejko et al. (2014) and Shokery et al. (2017).

The a^* parameter represents red and green colours. As expected, the value of this parameter was negative for yoghurts fortified with green or white tea extract, which indicates a slight shift of colour in the direction of greenness (Table 4). Negative values were also obtained for the control yoghurt, which is in good agreement with the reports of Najgebauer-Lejko et al. (2014). These authors presented results in which the a^* parameter increases along with increasing the concentration of green tea extract. The same relationship was observed in our study (Table 4). The lowest value of the coordinate a^* relates to yoghurt without additives. An increase in the addition of green or white tea extract paradoxically hinders the colour assessment, although one could have expected the increased intensity of greenness due to the presence of compounds such as chlorophyll in tea leaves (Najgebauer-Lejko et al., 2014). However, we observed that decreasing the greenness increases the a^* value due to a reduction in lightness (Table 3). Values showing a greater

Table 3. L^* (lightness/darkness[¥]) parameter of yoghurts as an effect of storage at 5°C[x]

	Storage time, days		
	3	7	14
N	72.27^{fg} ±0.02	74.76^{ab} ±0.09	75.39^{a} ±0.09
B4	66.92^{m} ±1.26	69.02^{kl} ±0.34	69.88^{jk} ±0.09
B8	64.33^{o} ±0.95	65.69^{n} ±0.48	66.54^{mn} ±0.22
B12	62.28^{p} ±1.08	63.39^{o} ±0.53	64.00^{o} ±0.29
R4	63.63^{o} ±1.09	65.82^{n} ±0.39	66.77^{m} ±0.20
R8	59.14^{r} ±0.88	61.30^{q} ±0.49	62.35^{p} ±0.25
R12	55.11^{t} ±2.00	57.89^{s} ±0.54	58.94^{r} ±0.21
G4	71.20^{hi} ±0.72	73.74^{cd} ±0.67	74.10^{bc} ±0.09
G8	71.34^{ghi} ±0.62	72.82^{def} ±0.26	73.47^{cde} ±0.11
G12	71.04^{hi} ±0.39	72.30^{fg} ±0.31	72.6^{ef} ±0.13
W4	69.76^{jk} ±0.70	71.99^{fgh} ±0.34	72.71^{ef} ±0.05
W8	69.28^{kl} ±1.01	70.58^{ij} ±0.35	71.15^{hi} ±0.14
W12	68.35^{l} ±0.43	69.41^{k} ±0.28	69.85^{jk} ±0.19

[¥]Positive and negative values indicate white and black, respectively.
[x]Data are presented as means ±standard deviation. Means with different superscript letters are significantly different, $p \leq 0.05$.

share of red colour were of course recorded in the case of red tea addition in each case, and black tea to yoghurts containing 8 and 12% extract. The positive values of the a^* parameter suggest a shift toward a red colour for yoghurts with the addition of either red or black tea, probably because of theabrownin present in the infusions of these teas (Najgebauer-Lejko et al., 2014). The storage time reduced the absolute values of the a^* parameter and correlated evidently with the increase in the lightness parameter. This phenomenon can be attributed to the decreasing level of phenolic compounds in yoghurts along with storage time, as reported by Amirdivani and Baba (2015).

For yoghurts with the addition of black and red tea, the b^* values were significantly higher ($P \leq 0.05$) than for yoghurts with the addition of green and white tea (Table 5). The lowest b^* value was recorded for the control yoghurt. In most cases, the storage time did not significantly change this parameter. Since the positive

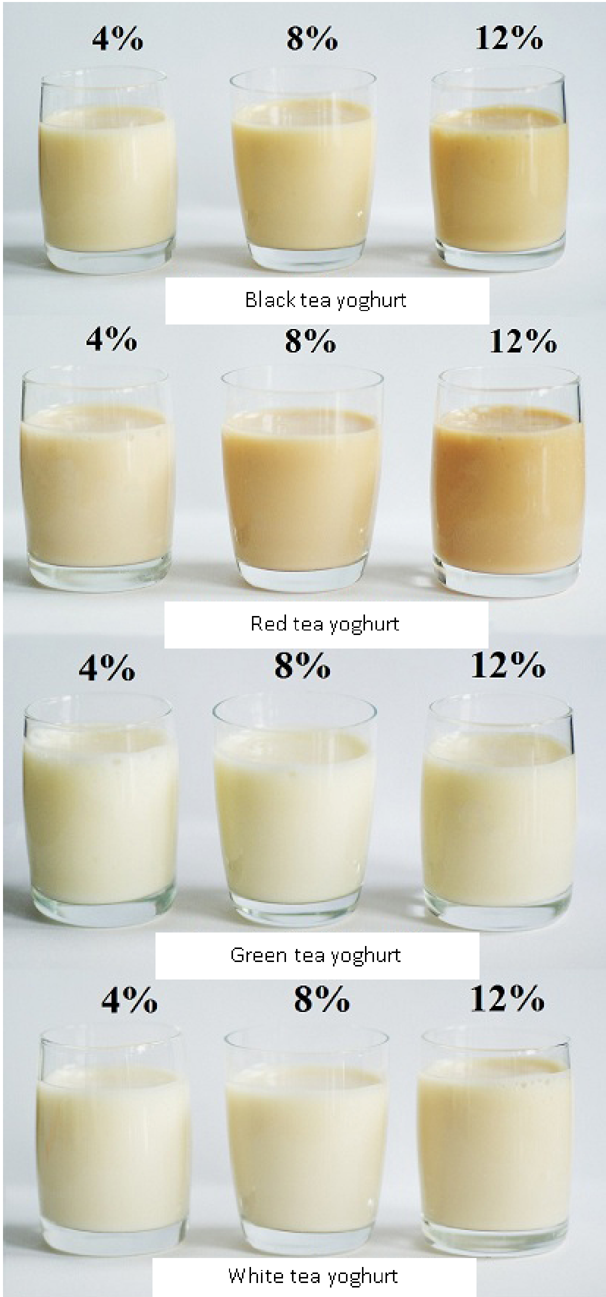

Fig. 1. Yoghurts with the addition of various tea extracts

b^* values represent the yellow colour, some correlation was found due to the presence of compounds affecting the red colour. A similar dependence on tea yoghurts was found by other authors (Najgebauer-Lejko et al., 2014; Shokery et al., 2017).

Table 4. *a** (red/green[¥]) parameter of yoghurts as an effect of storage at 5°C[x]

	Storage time, days		
	3	7	14
N	–2.77^{v} ±0.01	–2.40^{t} ±0.02	–2.37^{t} ±0.01
B4	–0.42^{k} ±0.14	–0.17^{j} ±0.06	–0.11^{j} ±0.03
B8	1.38^{i} ±0.19	1.25^{i} ±0.02	1.28^{i} ±0.03
B12	2.67^{g} ±0.14	2.45^{h} ±0.03	2.42^{h} ±0.03
R4	3.07^{f} ±0.10	2.84^{g} ±0.07	2.79^{g} ±0.05
R8	5.54^{d} ±0.09	5.18^{e} ±0.07	5.02^{e} ±0.05
R12	7.51^{a} ±0.67	6.85^{b} ±0.09	6.57^{c} ±0.04
G4	–2.59^{u} ±0.09	–2.14^{s} ±0.04	–1.98^{rs} ±0.02
G8	–2.33^{t} ±0.10	–1.93^{qrs} ±0.06	–1.78^{pqr} ±0.03
G12	–2.077^{s} ±0.15	–1.74^{pq} ±0.05	–1.63^{op} ±0.04
W4	–1.57^{op} ±0.24	–1.45^{no} ±0.04	–1.36^{n} ±0.03
W8	–1.05^{m} ±0.20	–0.76^{l} ±0.04	–0.72^{l} ±0.03
W12	–0.32^{jk} ±0.10	–0.20^{jk} ±0.04	–0.22^{jk} ±0.06

[¥]Positive and negative values indicate red and green, respectively.
[x]Data are presented as means ±standard deviation. Means with different superscript letters are significantly different, $p \leq 0.05$.

Table 5. *b** (yellow/blue[¥]) parameter of yoghurts as an effect of storage at 5°C[x]

	Storage time, days		
	3	7	14
N	6.24^{q} ±0.28	6.99^{p} ±0.04	6.70^{p} ±0.01
B4	14.35^{ef} ±0.32	14.37^{ef} ±0.09	13.98^{fg} ±0.09
B8	18.66^{c} ±0.57	18.41^{cd} ±0.21	17.96^{d} ±0.05
B12	21.69^{a} ±0.84	21.22^{ab} ±0.27	20.76^{b} ±0.14
R4	14.65^{e} ±0.25	14.76^{e} ±0.19	14.49^{ef} ±0.01
R8	18.55^{cd} ±0.23	18.67^{c} ±0.15	18.26^{cd} ±0.14
R12	21.26^{ab} ±1.13	21.31^{ab} ±0.21	20.75^{b} ±0.02
G4	7.92^{o} ±0.40	8.08^{o} ±0.11	8.05^{o} ±0.09
G8	8.64^{n} ±0.22	9.28^{lm} ±0.07	9.10^{m} ±0.12
G12	10.27^{k} ±1.14	10.23^{k} ±0.45	10.06^{k} ±0.09
W4	9.94^{k} ±0.67	9.80^{lk} ±0.07	9.64^{klm} ±0.06
W8	11.24^{j} ±0.37	11.92^{i} ±0.06	11.74^{i} ±0.08
W12	13.23^{h} ±0.10	13.63^{hgh} ±0.09	13.39^{h} ±0.09

[¥]Positive and negative values indicate yellow and blue, respectively.
[x]Data are presented as means ±standard deviation. Means with different superscript letters are significantly different, $p \leq 0.05$.

Sensory analysis

Sensory evaluation revealed that yoghurts with the addition of green tea extract were the most accepted (Fig. 2). The addition of extracts made of red, black and white tea resulted in lower values of all the sensory characteristics tested. Panellists indicated that yoghurt with a 4% green tea extract was the best, while yoghurt with a 12% addition of black tea extract was less accepted. The lowest rated feature was sweetness. This trait was influenced by the amount of extract added: the higher the percentage of tea extract, the less sweet the yoghurt for the evaluator. However, the consistency of the yoghurt was the highest-ranked feature. Also, in this case, the amount of added extract influenced the perception of the discriminant: the smaller the percentage of tea extract, the more desirable the yoghurt consistency. Due to the increase in the percentage of extract addition, the panellists gave a lower score when evaluating taste and aroma. This may be due to the bitterness generated by the tea ingredients in the yoghurt. Of all types of teas, black tea contains a higher level of theaflavins and tearubigins, which are responsible for bitter taste (Ošťádalová et al., 2014), therefore yoghurt with the addition of this extract faced the greatest disapproval of the panellists. In the available literature, there are few studies on sensory evaluation of yoghurt with the addition of tea. Shokery et al. (2017) evaluated yoghurt with the addition of green tea and reported lower scores than for the control yoghurt. In contrast, opposite results, apart from the texture assessment, were reported by Amirdivani and Baba (2013), who showed that the addition of green tea increases the production of lactic acid during lactose fermentation, which positively affects the yoghurt's taste.

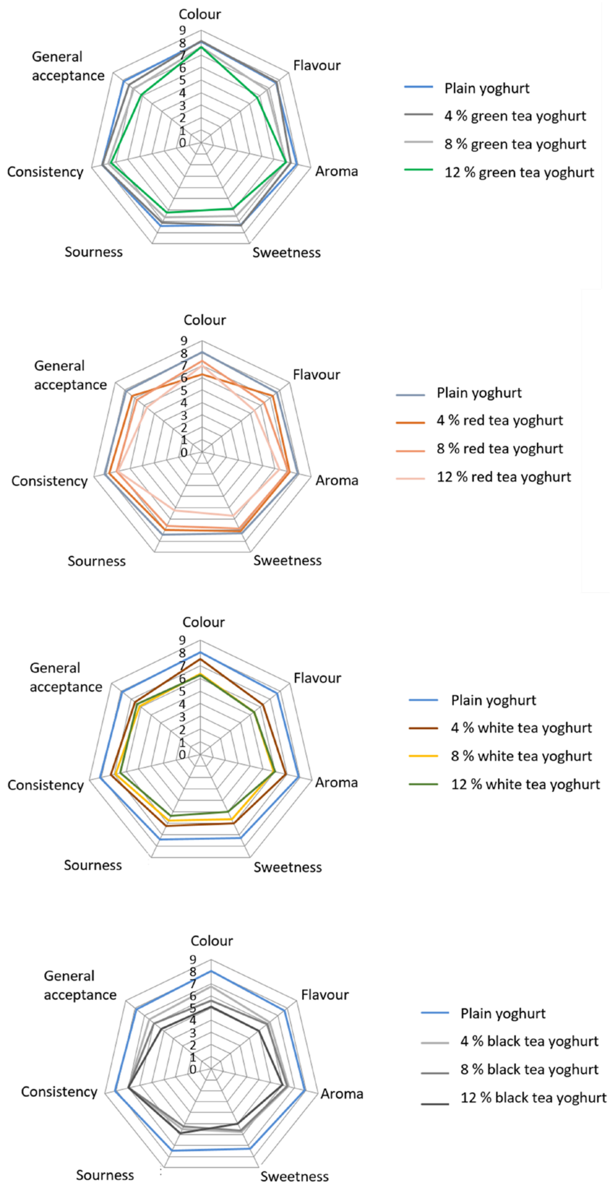

Fig. 2. Radar plots of sensory analysis of yoghurts with the addition of various tea extracts

CONCLUSIONS

Based on the physicochemical analysis, it can be concluded that the infusion derived from the different types of tea, as well as their concentration, did not play a noteworthy role in the acidity of the yoghurts tested. The viscosity of yoghurts with the addition of 8 and 12% tea extract was significantly lower compared to those with a 4% addition and the control yoghurt. The instrumental analysis of the colour confirmed the visual assessment. Furthermore, the changes in the colour intensity of formulated yoghurts correlated naturally with the colour and concentration of fortified extracts. However, conclusions from a sensory perspective seem to be crucial, especially in the context of the industrial application of the analysed extracts. The sensory results of our studies suggest unequivocally that the best sensory scores were received by plain yoghurt and the only additive commonly accepted by the panellist was the one fortified with green tea extract at the 4% concentration, the lowest examined.

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