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Health-promoting Properties Infusions of Hibiscus Flowers and Selected Berry Fruit Processing By-products

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Abstract

Aim: This study aimed to compare the health-promoting properties of hibiscus flowers infusions with pomace infusions from black chokeberry, blackcurrant, raspberry and strawberry.

Methodology: Five types of fruit pomace infusions were selected as the research material: hibiscus flowers infusion and infusions from black chokeberry, blackcurrant, raspberry and strawberry pomace. The total polyphenol content, antioxidant activity and colour parameters were determined.

Results: The highest content of phenolic compounds was found in hibiscus flowers infusion (453.25 mg GAE/L of infusion). Hibiscus flowers infusion also showed the highest antioxidant activity measured by DPPH, ABTS and FRAP tests. Among the tested infusions from selected berry fruit by-products, the infusion from chokeberry pomace was characterised by a high content of total phenolic compounds and antioxidant activity. The lowest total phenol content and antioxidant activity were found in the strawberry pomace infusion.

Implications and recommendations: Despite their popularity and variety of flavours, commercial fruit teas that use fruit by-products need to be standardised in terms of their health-promoting content. This means that there is no uniform, controlled standard that specifies the amount of specific beneficial health-promoting ingredients in each package of fruit tea. The authors' future research related to hibiscus flowers and berry pomace will focus on the influence of organoleptic characteristics on biological activity and the standardisation of the developed tea prototypes in terms of the content of health-promoting substances.

Originality/value: According to the research, hibiscus flowers infusion has the highest antioxidant and colouring properties. Chokeberry pomace infusion showed antioxidant properties comparable to hibiscus flowers infusion. Consequently, the health-promoting properties and low cost of fruit processing by-products may contribute to their broader use in the tea industry.

Keywords: hibiscus flowers, fruit pomace, health-promoting properties, infusions, upcycling, circular economy

1. Introduction

Consumers' growing needs and demands lead them to choose increasingly refined ways to meet their expectations. Food plays an essential role in human life, but it no longer serves solely as a means to satisfy hunger, and it contributes to improving consumers' health, increasing comfort and improving well-being. Customers expect product manufacturers to provide the desired sensory qualities and stand out with a high level of other quality attributes, which are expected to meet or exceed customer expectations – a critical element in the context of non-market competition among businesses. Furthermore, a clear research direction is closely related to a sustainable approach to using by-products from plant materials, aligning with the strategy of a circular economy (CE) (Komisja Europejska, 2020; Perra et al., 2022). Recently, there has been an increase in the consumption of fruits and vegetables, as well as juices, purees and smoothies, which are associated with the production of by-products. These residual by-products comprise a combination of seed remnants, fruit peels, or stems (Erline et al., 2022). On a global scale, producing by-products from fruit and vegetable processing has a significant impact, typically 25% to 50% of the total fruit mass being transformed into pulp (Okoro et al., 2021). Managing these waste products is a significant issue in the food processing industry. The global fruit processing industry generates over 190 million tons of waste annually (Błaszczyk et al., 2024). Numerous studies have shown that fruit pulp is a valuable source of many nutritious substances. Due to their properties, their popularity in producing fruit teas is increasing.

Analysis of the tea market showed that in 2020, global tea consumption amounted to approximately 6.3 billion kilogrammes and is projected to increase to 7.4 billion kilogrammes by 2025. Tea is the second most popular beverage in the world, after water (Kucia, 2022). In recent years, the consumption of fruit teas has increased, gradually replacing black teas (Bober and Oszmiański, 2004). Fruit teas are beverages prepared from dried fruits, flowers and herbs, often without any tea leaves of Camellia sinensis (Newerli-Guz, 2010). The popularity of fruit teas has grown due to their natural ingredients and caffeine-free nature, attracting those seeking alternatives to traditional tea or coffee. According to many sources, the most well-known fruit teas include hibiscus, raspberry, wild rose, blackcurrant, and cranberry teas (Kula, 2022).

Hibiscus is known for its intense flavour and health benefits, and it plays a key role as the main ingredient in many fruit teas worldwide (Karaś et al., 2015). However, in recent years, there has been a problem with the limited availability of this plant on the global market, leading to insufficient access to hibiscus in Poland and, subsequently, its high price, prompting the search for alternative substitutes with similar colouring and health properties.

A promising alternative to hibiscus could be domestic by-products of fruit processing, such as residues from black chokeberry, raspberry, blackcurrant, and strawberry processing. These products positively impact the body, regulating physiological processes and metabolic transformations. They also support the natural immune system, maintain healthy skin, stimulate regeneration and boost energy and concentration (Wieloch et al., 2012).

Infusions made from berry fruits and their by-products prove to be an excellent source of valuable bioactive compounds, which exhibit antioxidant activity and the ability to inhibit the growth of various cancer cell lines (Tarko et al., 2012). The mineral components contained in these fruits also play a crucial role, acting as regulators of many physiological processes in the human body, supporting nerve conduction, electrolyte balance and numerous other vital functions. They contribute to maintaining healthy bones and muscle function and play a significant role in the functioning of the nervous system (Nirmal et al., 2021).

So far, research on the use of by-products in the preparation of infusions has focused mainly on ingredients such as a mixture of by-products from various sources (Acar et al., 2022), banana peel (Pure and Pure, 2016), and avocado peel (Rotta et al., 2015). The possibility of using dried chokeberry, blackcurrant, raspberry and strawberry pomace as ingredients for infusions and potential substitutes for hibiscus flowers has not been thoroughly investigated in terms of antioxidant properties. Despite their popularity and diverse flavours, commercial fruit teas need to be standardised in terms of their content of health-promoting substances. This means there is no uniform, controlled standard specifying the quantity of specific beneficial ingredients, such as polyphenols or vitamins, in each package of fruit tea. Therefore, there is a need for scientific research and the development of more precise quality standards for fruit teas.

The study aimed to compare the health-promoting properties of infusions of hibiscus flowers and residues from black chokeberry, blackcurrant, raspberry, and strawberry processing.

2. Materials and Methods Research

2.1. Preparation of Infusions for Analysis

The raw materials for the research were commercially available dried hibiscus flowers (*Hibiscus sabdariffa L.)* and chokeberry (*Aronia melanocarpa* Michx. E.), blackcurrant (*Ribes nigrum* L.), raspberry (*Rubus idaeus* L.) and strawberry (*Fragaria ananassa*) pomace (intermediate products used in the production of teas) . The criterion guiding the selection of these berry species was the structure of the harvest of the most popular berry fruits in Poland in 2023. The research material consisted of five infusions: hibiscus flowers, black chokeberry pomace, blackcurrant pomace , raspberry pomace and strawberry pomace. Three independent samples of infusions from each raw material were prepared for determination. The infusions were prepared according to the PN ISO 3103:1996 standard. Each infusion was prepared in hot beakers by pouring 2 grams of the herb into 200 mL of freshly boiled tap water and covered with Petri dishes. The water temperature was 95˚C. The steeping time for each infusion was 6 minutes. Sweetening agents were not added to the prepared infusions. After the appropriate steeping time, the infusions were poured into beakers, separating the solids from the infusions.

2.2. Determination of Total Phenolic Content (TPC)

The total phenolic content was determined using a spectrophotometric method (Singleton and Rossi, 1965). Sequentially, in 10 mL volumetric flasks, 5 mL of distilled water was added, followed by 0.5 mL of Folin-Ciocalteu reagent and 0.1 mL of tea infusion. The concentration of the added infusion was experimentally determined and depended on the content of phenolic compounds. After 3 minutes of incubation at room temperature, 1.5 mL of a 20% sodium carbonate solution was added to the flasks, followed by filling them up to the mark with distilled water. After 2 hours, absorbance was measured at a wavelength of 725 nm using a Jasco V-770 spectrophotometer. A similar reference was prepared by adding distilled water instead of the tea infusion. The content of phenolic compounds in the infusions was determined based on a standard curve and expressed in mg of gallic acid equivalents (GAE) per litre of infusion.

2.3. Measurements of Antioxidant Activity by DPPH

The evaluation of antioxidant properties of infusions obtained from fruit tea pomaces was carried out following the method of Sanchez-Moreno et al. (1998) with a modification involving the use of a DPPH radical solution with a concentration of 0.0025 g/100 mL in 96% ethyl alcohol. The DPPH radical (2,2-diphenyl-1-picrylhydrazyl) is stable under normal conditions. This method involves assessing the degree of reduction of the DPPH radical by antioxidants present in the infusions from fruit tea pomaces.

For the analysis, 2.4 mL of the DPPH radical solution and 0.1 mL of the sample were taken. Absorbance measurements were taken every half minute for 10 minutes at a wavelength of 515 nm using a Jasco V-770 spectrophotometer. The antioxidant activity of the infusions was determined based on a standard curve and expressed in mmol Trolox per litre of infusion.

2.4. Measurements of Antioxidant Activity by ABTS

In assessing the ability to scavenge free radicals, the reaction of the examined samples with ABTS cation radicals was used. The determination was carried out following the method of Re et al. (1999).

The ABTS cation radical solution was diluted with phosphate buffer (PBS) at pH 7.4 to absorb 0.700 (± 0.020) at λ = 734 nm. Then, 0.03 mL of the sample was added to 3 mL of the ABTS solution. Absorbance was measured at 734 nm after 6 minutes of sample incubation at 37˚C using a Jasco V-770 spectrophotometer. The antioxidant activity of the infusions was determined based on a standard curve and expressed in mmol Trolox per litre of infusion.

2.5. Measurements of Antioxidant Activity by FRAP

The reducing power of the infusions was assessed using the FRAP test, based on the methodology of Benzie and Strain (1996). This method relies on evaluating the ability of the infusion to reduce the iron Fe^{3+}-TPTZ (2,4,6-tripyridyl-s-triazine) complex to Fe^{+2}-TPTZ, which is indicative of antioxidant properties.

The FRAP analysis was performed at a wavelength of 593 nm using a Jasco V-770 spectrophotometer. To determine the reducing power FRAP, a reaction mixture was prepared, containing 10 mmol/L TPTZ solution in 40 mmol/L HCl, 20 mmol/L $FeCl_3$ and 0.1 mol/L acetic acid buffer (pH = 3.6) in a volume ratio of 1:1:10. For analysis, 1.95 mL of the reaction mixture and 0.05 mL of the infusion were taken. The samples were shaken for 5 seconds and left at room temperature for 8 minutes before measurement. A control sample comprised 1.95 mL of the reaction mixture and 0.05 mL of distilled water. The antioxidant activity of the infusions was determined based on a standard curve and expressed in mmol Trolox per litre of infusion.

2.6. Instrumental Colour Measurement (L*a*b*, L*C*h*)

Colour parameters were determined in the CIE L*a*b* colour space, standardised by the International Commission on Illumination (CIE) (ISO/CIE 11664-4:2019) and in the L*C*h° colour space.

The measurement of colour parameters was performed in the visible light (VIS) range from 380 nm to 780 nm using a 10° observer type and a D65 illuminant in a Jasco V-770 spectrophotometer in three repetitions for each type of infusion. The instrument was calibrated using two cuvettes containing distilled water. To conduct colour measurements, the examined infusions were transferred to glass measuring cuvettes.

Three components were defined in the CIE L*a*b* colour space: L*, ranging from 100 (perfectly white) to 0 (perfectly black), representing brightness, while a* and b* express colour chromaticity. The value of a* determines shades of red (+a*) and green (–a*), while b* represents shades of yellow (+b*) and blue (–b*). The L*C*h° colour space is also based on three components, where L* describes brightness, C* indicates colour saturation and h° represents the hue angle of colour (0-360°) (Gliszczyska-Świgło, 2016).

The total colour difference ΔE^*_{ab} was determined based on the parameters L*, a*, b*:

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0,5} ,$$

where: ΔL*, Δb*, Δa* – difference between the value for the infusion from the sample and the value for water.

2.7. Statistical Analysis

The results represent the arithmetic mean of at least three parallel determinations. Analysis of variance (ANOVA) was performed to compare the mean values. To verify the significance of differences between mean values, the Tukey test was applied using the Statistica 13.3 software. A significance level of $p < 0.05$ was adopted for statistical estimation.

3. Results and Discussion

Table 1 presents the content of phenolic compounds and the antioxidant activity of the analysed infusions from hibiscus flowers and pomace infusions from black chokeberry, blackcurrant, raspberry, and strawberry. The infusions significantly differed in both total phenolic compound content and antioxidant properties.

Table 1. Content of phenolic compounds and antioxidant activity of hibiscus flowers infusions and chokeberry, blackcurrant, raspberry and strawberry pomace
Tabela 1. Zawartość związków fenolowych ogółem i aktywność przeciwutleniająca naparów z kwiatów hibiskusa oraz wytłoków z aronii, czarnej porzeczki, maliny i truskawki

Infusion	TPC (mg GAE/L)	ABTS (mM Trolox/L)	DPPH (mM Trolox/L)	FRAP (mM Trolox/L)
Hibiscus flowers	453.25 ± 2.40^a	2.99 ± 0.02^a	0.68 ± 0.01^a	0.81 ± 0.02^a
Black chokeberry pomace	305.75 ± 2.40^b	2.45 ± 0.03^b	0.60 ± 0.00^b	0.61 ± 0.01^b
Blackcurrant pomace	225.50 ± 4.21^c	1.49 ± 0.01^c	0.47 ± 0.01^c	0.54 ± 0.01^c
Raspberry pomace	178.86 ± 2.56^d	1.12 ± 0.02^d	0.41 ± 0.02^d	0.50 ± 0.01^d
Strawberry pomace	156.56 ± 2.77^e	0.62 ± 0.04^e	0.11 ± 0.01^e	0.23 ± 0.01^e

Note: The results given as mean value ± standard deviation; a, b, c, d, e – homogeneous groups within the columns differ statistically significantly ($p < 0.05$).

Source: own work.

Among the examined infusions, the highest total phenolic compound (TPC) content was observed in the infusion obtained from hibiscus flowers (453.25 ± 2.40 mg GAE/L). The lowest TPC content was found in the strawberry pomace infusion, which amounted to 156.56 ± 2.77 mg GAE/L. Statistically significant differences were observed in the total content of phenolic compounds between the infusions analysed. In the study by Tokusoglu (2019), the TPC value in infusions prepared from black chokeberry lyophilisate was 101.02 mg GAE/100 mL. The preparation process of these infusions differed in parameters such as steeping time, the amount of evaporated water, and the treatments applied to the black chokeberry. In this study, hibiscus exhibited the highest total phenolic compound content. Similar results were obtained by Wong, Lim and Chan (2010), with TPC values ranging from 301 to 2080 mg GAE/100 g, depending on the plant species, confirming its significance in fruit herbal tea production.

Due to different factors that influence antioxidant activity in complex heterogeneous biological systems, the evaluation cannot be used only with a one-assay protocol. For that reason, three methods were chosen to evaluate the antioxidant capacity (ABTS and DPPH, FRAP) of infusions, where ABTS is based on the hydrogen atom transfer mechanism. In contrast, DPPH and FRAP are based on the electron transfer mechanism (Kaprasob et al., 2018).

The ABTS radical test revealed that the infusion obtained from hibiscus flowers had the strongest antioxidant properties (2.99 ± 0.02 mM Trolox/L), which were twice as high as those of the blackcurrant pomace infusion (1.49 ± 0.01 mg Trolox/L). Among the infusions analysed, the black chokeberry pomace infusion also showed high antioxidant activity (2.45 ± 0.03 mM Trolox/L). The strawberry pomace infusion exhibited the lowest antioxidant activity among all infusions, with a value of 0.62 ± 0.04 mM Trolox/L. In the study by Borowiec et al. (2023), the polyphenolic compound content in ground fruits, measured using the ABTS radical test, was 57.09 µM TE and for the DPPH radical test, it was 53.01 µM TE. In the research by De Santis et al. (2022), antioxidant properties amounted to 1770 µM TE/100 g for raspberry seeds and skin pomace. Based on the results in De Santis et al. (2022), it can be assumed that a higher content of bioactive compounds is present in fruit skins.

Among the infusions examined, the infusion obtained from hibiscus flowers exhibited the highest radical scavenging activity, as determined by the DPPH test (0.68 ± 0.01 mM Trolox/L), followed by the infusion of black chokeberry pomace (0.60 ± 0.00 mM Trolox/L). The strawberry pomace infusion showed the lowest radical scavenging activity, amounting to 0.11 ± 0.01 mM Trolox/L. Statistically significant differences in radical scavenging activity were observed among the examined infusions. Tolić (2017) obtained a DPPH result of 14.6 mM Trolox/L. The difference in preparing infusions by Tolić (2017) involved using lyophilised black chokeberry pomace and performing extraction twice, resulting in a higher DPPH value. Considering the results of the total phenolic compound content and antioxidant activity in black chokeberry infusions, it can be concluded that black chokeberry pomace provides an interesting alternative to hibiscus. The strawberry pomace infusion exhibited the lowest values among all infusions. The research results of Bermúdez-Oria et al. (2020) confirmed the low content of antioxidant compounds in strawberry puree. In that study (Bermúdez-Oria et al. ,2020) antioxidant analysis was 15.8 mM Trolox/L, which is significantly higher than for this study, which measured the antioxidant activity of fruit pomace infusions. However, the result of the FRAP test conducted by Bermúdez-Oria et al. (2020) was 19.5 mM Trolox/L, which is lower compared to our research on fruit pomace infusions. Bermúdez-Oria et al. (2020) conducted their research using properly prepared puree from fresh local fruits, and the differences in the results may be attributed to variations in the strawberry form. However, considering the values of all components, strawberries are likely to have relatively low levels of health-promoting compounds.

The samples examined exhibited significant variability in reducing power with the infusions of hibiscus flowers (0.81 ± 0.02 mM Trolox/L). The infusions of black chokeberry pomace (0.61 ± 0.01 mM Trolox/L) showing the highest reducing potential, followed by the infusion of blackcurrant pomace (0.54 ± 0.01 mM Trolox/L), and raspberry pomace (0.50 ± 0.01 mM Trolox/L). The strawberry pomace infusion had the lowest reducing power (0.23 ± 0.01 mM Trolox/L).

Natural plant raw materials have additional properties, such as a specific aroma or distinctive natural colour, which complement and symbiotically influence the quality of the final product. Instrumental colour measurement of infusions can help to assess the quality of the raw material as a result of exposure to visible and ultraviolet light, which results in loss of nutrients, discolouration, and an altered sensory experience. Table 2 presents the colour parameters of the examined infusions in the L*a*b* and L*C*h* colour spaces. Among the samples tested, the infusion of hibiscus flowers differed significantly in brightness from the other infusions (L* = 72.66). This value was significantly lower compared to strawberry pomace infusion (L* = 99.57) or blackcurrant pomace infusion (L* = 98.64).

Table 2. Colour parameters infusions for hibiscus flowers and black chokeberry, blackcurrant, raspberry and strawberry pomace
Tabela 2. Parametry barwy naparów z kwiatów hibiskusa oraz wytłoków z aronii, czarnej porzeczki, maliny i truskawki

Infusion	Parameter					
	*L**	*a**	*b**	*C**	*h°*	ΔE^*_{ab}
Hibiscus flowers	72.66 ± 0.04^e	48.23 ± 0.03^a	5.27 ± 0.04^a	60.23 ± 0.04^a	48.51 ± 0.02^e	54.12 ± 0.04^a
Black chokeberry pomace	95.03 ± 0.01^d	1.24 ± 0.01^b	1.51 ± 0.00^c	1.95 ± 0.01^b	50.68 ± 0.29^d	2.45 ± 0.02^d
Blackcurrant pomace	98.64 ± 0.03^c	0.46 ± 0.00^c	0.76 ± 0.01^e	0.89 ± 0.01^e	59.12 ± 1.02^c	1.94 ± 0.03^e
Raspberry pomace	98.82 ± 0.01^b	-0.03 ± 0.00^d	1.53 ± 0.00^b	1.53 ± 0.00^c	91.02 ± 0.04^b	2.36 ± 0.01^c
Strawberry pomace	99.57 ± 0.01^a	-0.13 ± 0.02^e	1.08 ± 0.01^d	1.09 ± 0.02^d	97.04 ± 0.03^a	2.88 ± 0.01^b

Note: The results given as mean value ± standard deviation; a, b, c, d, e – homogeneous groups within the columns differ statistically significantly ($p < 0.05$).

Source: own work.

The infusion of hibiscus also stood out in terms of its red colour content; parameter a* for this infusion was 48.23. The hibiscus flowers infusion exhibited a significantly higher yellow colour content (b* = 5.27) compared to the other solutions (strawberry pomace infusion b* = 1.08; black chokeberry pomace infusion b* = 1.51). Considering all parameters, it can be concluded that the colour of the hibiscus flowers infusion was significantly darker than that of the other infusions and exhibited the highest intensity. In the study by Kidoń et al. (2023), the L* parameter for the hibiscus infusion was 84.6. The yellow hue content in the solution colour was also comparable, with the b* parameter at 4.2. Slightly different values were obtained by Paraiso et al. (2021), where the hibiscus infusion was significantly darker (L* = 20.72) and exhibited a lower red colour content. The lower L* value may result from a different infusion procedure compared to the infusion prepared in this study. The yellow colour content obtained by Bober et al. (2004) is comparable to the results obtained in this study (b* = 4.23). Bober et al. (2004) showed that the black chokeberry pomace infusion was significantly darker, with an L* parameter of 48.27. The other parameters, a* = 64.74 and b* = 46.31, also exhibited higher values than those obtained in this study, which can be attributed to the way the authors prepared the infusion. In the study cited by Bober et al. (2004), the infusion was obtained through maceration using room-temperature water. This could lead to lower degradation of temperature--sensitive anthocyanin pigments, making the solution colour more intense (Enaru et al., 2021). Azman et al. (2022) obtained a darker and more intense solution colour using acidic pH water for extraction in the case of blackcurrant. For the solution extracted using water with a pH of 3.0, the colour was described as dark red. The colour parameters were L* = 28.0, a* = 43.5, b* = 9.8. The solution obtained by Azman et al. (2022) exhibited a lower brightness and simultaneously a higher content of red and yellow colours. The highest colour saturation (C*) was recorded for the hibiscus infusion, indicating that the infusion was highly pigmented. The values of the h° parameter for the raspberry and strawberry pomace infusions were 91.02° and 97.04°, respectively, indicating orange-yellow shades in the sample. Two colours recorded in CIELAB colour space can be compared by the total colour difference ΔE*ab, which is the distance between these colours in three-dimensional CIELAB space. The interpretation given by Cserhalmi, Sass-Kiss, Toth-Markus and Lechner (2006) was used to analyse this parameter: 0-0.5 – imperceptible colour change, 0.5-1.5 – slightly noticeable colour change, 1.5-3 – noticeable colour change, 3-6 – well visible colour change. In the case of the infusion of hibiscus flowers, the value of ΔE*ab was above 6, which indicated a clear difference in the colour of the infusion compared to the other samples.

4. Conclusion

According to the authors' research, hibiscus infusion has the highest antioxidant and colouring properties. However, among the tested infusions from selected berry fruit by-products, the infusion from chokeberry pomace was characterised by a high content of total phenolic compounds and antioxidant activity, and was comparable to the hibiscus infusion. Therefore, this is an interesting way to use domestic fruit processing by-products in the composition of fruit tea, which are characterised by similar health-promoting properties. Consequently, the health-promoting properties and low cost of fruit processing by-products may contribute to their broader use in the tea industry.

Future studies by the authors on hibiscus flowers and berry pomace will concentrate on the influence of organoleptic properties on biological activity and the standardisation of the developed tea prototypes in terms of the content of health-promoting substances.

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Prozdrowotne właściwości naparów z kwiatów hibiskusa i wybranych produktów ubocznych przetwórstwa owoców jagodowych

Streszczenie

Cel: Celem pracy było porównanie prozdrowotnych właściwości naparów z kwiatów hibiskusa z naparami z wytłoków z aronii, czarnej porzeczki, maliny i truskawki.

Metodyka: Materiał badawczy stanowiło pięć rodzajów naparów z wytłoków owocowych: napar z kwiatów hibiskusa oraz napar z wytłoków z aronii, czarnej porzeczki, malin i truskawek. Określono ogólną zawartość związków fenolowych, aktywność przeciwutleniającą i parametry barwy.

Wyniki: Oznaczono ogólną zawartość związków fenolowych, aktywność przeciwutleniającą oraz parametry barwy. Największą ogólną zawartość związków fenolowych stwierdzono w naparze z kwiatów hibiskusa (453,25 mg GAE/L naparu). Napar z kwiatów hibiskusa wykazał także najwyższą aktywność antyoksydacyjną mierzoną testami DPPH, ABTS i FRAP. Spośród badanych naparów z wybranych produktów ubocznych owoców jagodowych napar z wytłoków aronii charakteryzował się wysoką zawartością związków fenolowych ogółem oraz działaniem przeciwutleniającym. Najniższą ogólną zawartość związków fenolowych i aktywność przeciwutleniającą stwierdzono w naparze z wytłoków truskawkowych.

Implikacje i rekomendacje: Pomimo swojej popularności i różnorodności smaków komercyjne herbatki owocowe, w których wykorzystywane są owocowe produkty uboczne, wymagają standaryzacji pod względem zawartości substancji prozdrowotnych. Oznacza to, że nie ma jednolitego, kontrolowanego standardu określającego ilość konkretnych korzystnych składników prozdrowotnych w każdym opakowaniu herbatki owocowej. Przyszłe badania autorów związane z kwiatami hibiskusa i wytłokami jagodowymi będą się koncentrować na wpływie cech organoleptycznych na aktywność biologiczną oraz standaryzacji opracowanych prototypów herbatek pod względem zawartości substancji prozdrowotnych.

Oryginalność/wartość: Według badań autorów napar z kwiatów hibiskusa charakteryzował się najwyższymi właściwości przeciwutleniającymi i barwiącymi. Napar z wytłoków aronii wykazał właściwości przeciwutleniające porównywalne z naparem z kwiatów hibiskusa. W konsekwencji właściwości prozdrowotne oraz niski koszt produktów ubocznych przetwórstwa owoców mogą się przyczynić do ich szerszego wykorzystania w przemyśle herbacianym.

Słowa kluczowe: kwiaty hibiskusa, wytłoki owocowe, właściwości prozdrowotne, napary, waloryzacja produktów ubocznych, gospodarka o obiegu zamkniętym