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ORIGINAL ARTICLE

THE USE OF FRUIT EXTRACTS FOR PRODUCTION OF APPLE CHIPS WITH ENHANCED ANTIOXIDANT ACTIVITY

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ABSTRACT

Background. Style and pace of life make consumers more willing to reach for snack products. This group of processed food includes, among others, fruit chips. Due to the increasing incidence of diseases associated with the excessive exposure to free radicals foods enriched with antioxidant compounds, eg. polyphenols, can be introduced into the sale.
Objective. The aim of the study was to use the fruit extracts for the production of apple chips with enhanced antioxidant activity.
Material and methods. 'Golden Delicious' variety of apple fruit was used to produce chips. Apple chips were prepared by slicing, soaking in a sugar solution and pre-drying in a microwave oven. Chips were enriched with extracts prepared from fruits of chokeberry, five-flavor berry, Cornelian cherry, woodland hawthorn, goji berry, Japanese quince and cranberry microcarpa. For this purpose, pre-dried apple slices were soaked (5 min) in ethanolic extract of fruits and then dried to achieve a 5% moisture content. Chips were sensory evaluated and their antioxidant activity and total polyphenols content were determined.
Results. All enriched apple chips were characterized by high antioxidant activity and a relatively high value of total polyphenols content. Chips soaked in extracts of five-flavor berry, cranberry and goji berry were characterized by the highest antioxidant potential. Samples obtained by using chokeberry and Cornelian cherry extracts showed the highest content of polyphenols. High sensory attractiveness of enriched chips was also showed. The chips with the addition of five-flavor berry extract were exceptions. Their taste was not acceptable.
Conclusions. Fruit extracts are a valuable material for chips enrichment. Taking into account all the analyzed differentiators, extracts of Japanese quince, goji berry and woodland hawthorn were found to be the best enriching additives. The chips soaked in extract of five-flavor berry, despite their high antioxidant activity, were disqualified due to very low score of sensory evaluation.

Key words: *apple chips, food supplementation, antioxidant compounds, polyphenols*

STRESZCZENIE

Wprowadzenie. Tempo oraz styl życia sprawiają, że konsumenci coraz chętniej spożywają produkty przekąskowe. Do wyrobów takich należą m.in. chipsy owocowe. Ze względu na rosnącą zachorowalność na choroby związane z nadmierną ekspozycją na wolne rodniki celowe wydaje się wprowadzanie do sprzedaży żywności wzbogaconej związkami przeciwutleniającymi, np. polifenolami.
Cel. Celem badań było wykorzystanie ekstraktów owocowych do wytwarzania chipsów jabłkowych o podwyższonej aktywności przeciwutleniającej.
Materiały i metody. Z jabłek odmiany Golden Delicious przygotowano chipsy jabłkowe poprzez pokrojenie na plastry, wysycenie w zalewie cukrowej i wstępne podsuszenie w piecu mikrofalowym. Chipsy jabłkowe wzbogacano ekstraktami etanolowymi z owoców aronii, pigwowca japońskiego, derenia jadalnego, żurawiny drobnoowocowej, głogu dwuszyjkowego, cytryńca chińskiego i kolcowoju chińskiego. W tym celu podsuszone plastry jabłek moczono (5 min) w ekstrakcie etanolowym z owoców. Następnie plastry dosuszono owiewowo do osiągnięcia 5% wilgotności. Uzyskane chipsy oceniano sensorycznie oraz oznaczano ich aktywność przeciwutleniającą i zawartość polifenoli ogółem.
Wyniki. Wszystkie wzbogacone chipsy jabłkowe miały wyższą aktywność antyoksydacyjną i zawartość polifenoli ogółem niż próby kontrolne. Największym potencjałem antyoksydacyjnym charakteryzowały się chipsy z dodatkiem ekstraktu z cytryńca, żurawiny i goji. Najwyższą zawartością polifenoli odznaczały się chipsy z dodatkiem ekstraktu z aronii oraz derenia. Wykazano także wysoką atrakcyjność sensoryczną chipsów z dodatkami ekstraktów owocowych. Wyjątek stanowiły chipsy z dodatkiem cytryńca, których smak nie był akceptowany.
Wnioski. Ekstrakty owocowe stanowią cenny surowiec wzbogacający chipsy owocowe. Wykazano, że najbardziej wartościowymi ekstraktami owocowymi wzbogacającymi chipsy jabłkowe, ze względu na wysoki potencjał antyoksydacyjny i wyniki oceny sensorycznej, były ekstrakty z owoców pigwowca, goi i głogu. Chipsy z dodatkiem ekstraktu z cytryńca, mimo wysokiej aktywności przeciwutleniającej, uzyskały niską ocenę sensoryczną.

Słowa kluczowe: *chipsy jabłkowe, suplementacja żywności, związki antyoksydacyjne, polifenole*

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INTRODUCTION

Reactive oxygen species (ROS), including free radicals, are formed in all living organisms under the influence of many factors. Therefore it is so important that the antioxidant system functions correctly in order to prevent development of any pathological processes caused by free radicals, that may lead to many diseases including cardiovascular diseases and cancer. Antioxidants are compounds that are able to inactivate ROS. They play a significant role in preventing damage caused by free radicals as they can inhibit ROS production and participate in their transformation into inactive derivatives. Antioxidants include tocopherols, carotenoids, vitamin C, and polyphenols, which make up the most important and abundant group. Fruits and vegetables, tea and wine are the main sources of antioxidants [4, 7].

Chips are popular food products commonly consumed around the world. They are predominant part of the "snack foods", generally eaten between meals. Chips might be made by drying, expanding, extruding, baking or frying. These products are more shelf-stable and attractive for consumers in comparison to the unprocessed raw material. Currently, the most popular snack is potato chips. In the snack food market, there are many varieties of chips manufactured using various spices, flavorings and aromatics [8, 13].

Growing consumer demand for functional food, as well as awareness and understanding of dietary recommendations to eat more fruits and vegetables, encourages food manufacturers to develop new products, which are a valuable source of micro- and macronutrients, fiber and polyphenolic compounds [18]. On the other hand style and pace of life and eating habits can lean buyers to choose processed snacks. Therefore, snacks made from fruit and vegetables are gaining popularity, because they are fat-free, low-calorie products with a low salt content [8].

Enrichment of food products with polyphenols is a type of fortification aimed at shaping the product properties desired by consumers. The presence of the bioactive components improves the quality and affects a specific physiological activity of the body. However, the antioxidant activity of the polyphenols, their content, as well as the absorption capacity of the gastrointestinal tract should be noted [12].

The aim of the study was to use the fruit extracts for the production of apple chips with enhanced antioxidant activity.

MATERIAL AND METHODS

Apple fruits (*Malus domestica* Borkh.) 'Golden Delicious' were used to produce chips. Extracts were prepared from chokeberry (*Aronia melanocarpa* (Michx.) Elliott), five-flavor berry (*Schisandra chinensis* (Turcz.) Baill.), Cornelian cherry (*Cornus mas* L.), woodland hawthorn (*Crataegus oxyacantha* L.), goji berry (*Lycium chinense* Mill.), Japanese quince (*Chaenomeles japonica* (Thunb.) Lindl. ex Spach.) and cranberry microcarpa (*Oxycoccus microcarpus* (Turcz. ex Rupr.) Schmalh.). Fruit came from the pomological orchard of University of Agriculture in Krakow, located in Garlica Murowana near Krakow. Part of the fruits was purchased from the producers of organic farming in Malopolska and Podkarpacie areas. Dried goji berries and five-flavor berries were bought in shops distributing organic food.

Extracts preparation

90 ml of ethanol at a concentration of 80% vol. was added to 10 g of fruits. The high shear homogenizer (19 000 rpm; 5 min; Ultra-Turrax T25 Basic, IKA) was used for extraction. The obtained extracts were filtered, adjusted to 100 ml with the solvent and stored at -20°C.

Preparation of apple chips supplemented with fruit extracts [19]

Apples were washed, thoroughly dried with paper towel and sliced (with peel and apple core) into slices of 3.5 mm thickness. Then the slices were soaked for 1 minute in a saturating mixture containing sucrose (20%), apple juice concentrate (5%), citric acid (0.25%) and SO_2 (0.12%). After draining off the apple slices were treated with microwave (a microwave generator Mars Express, 300 W, 5 min) and subsequently pre-dried in an air-oven (90°C, 2 h). In order to enrich chips with the antioxidant compounds, they were soaked (5 min) in the fruit ethanolic extract. At the end the slices were dried to achieve a 5% moisture content.

Evaluation of the antioxidant activity [20]

The sample of crushed chips was extracted (10 g of chips + 90 ml of methanol) using a high shear homogenizer (19 000 rpm for 5 min). The obtained solutions were filtered and adjusted to a 100 ml by the solvent used.

The antioxidant activity was determined by using the active radical cation ABTS (2,2'-azino-*bis* (3-ethylbenzothiazoline-6-sulphonic acid), Sigma). ABTS radical was generated by chemical reaction between 7 mM aqueous solution of diammonium salt of 2,2'-azino-*bis* (3-ethylbenzthiazoline-6-sulfonate) and 4.9 mM potassium persulfate solution ($K_2S_2O_8$). The solution was kept overnight in the dark at ambient temperature, to terminate the reaction and to stabilize ABTS cation. Just before the analysis, the concentrated solution of ABTS was diluted with phosphate buffer saline (PBS) at pH 7.4, to obtain absorbance value of final solution A = 0.70 ± 0.02 ($ABTS_{0,7}$) measured with a spectrophotometer (Beckman DU 650) at a wavelength of 734 nm. 100 µL of the appropriate diluted samples were added to 1 mL $ABTS_{0,7}$ and the absorbance was measured 6 minutes after mixing. The antioxidant capacity of the samples was calculated using a standard curve performed on solutions of synthetic vitamin E (Trolox - 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, Sigma) and expressed in mg of Trolox/100 mL.

Determination of total polyphenol content [20]

The sample of crushed chips was extracted (10 g of chips + 90 ml of methanol) using a high shear homogenizer (19 000 rpm for 5 min). The obtained solutions were filtered and adjusted to a 100 ml by the solvent used.

Total polyphenol content was determined by the modified *Folin-Ciocalteu* method. 45 mL of double-distilled water was added to 5 mL of appropriately diluted chips' extract or standard (catechin). Then 5 ml of such solution was mixed with 0.25 mL of *Folin-Ciocalteu* reagent (water dissolved at 1:1 v/v, Sigma) and 0.5 mL of 7% Na_2CO_3 (POCh) were added. Samples were incubated for 30 minutes in the dark, before measuring the absorbance on a spectrophotometer at the 760 nm (spectrophotometer Beckman DU 650, against methanol as a blank). The results of total polyphenolic content were obtained based on calibration curve and were expressed as mg of (+) catechin per 100 mL of beverage.

Sensory evaluation of apple chips [15]

Evaluation was carried out by the panel comprising 20 qualified and tested for their sensory sensitivity people. They assessed five basic quality factors (flavor, crispness, color, shape and odor). For the sensory evaluation the 5-point scale with following weight factors: the flavor (0.3); crispness (0.25); color (0.15); shape (0.2) and odor (0.1).

Statistical analysis

There were a minimum of three repetitions of the analysis and the results are shown as the arithmetic mean with standard deviation (± SD). Statistical analysis was performed using InStat v. 3.01 (GraphPad Softwere Inc., USA). A single-factor analysis of variance (ANOVA) with post hoc *Tukey's* test was applied to determine the significance of differences between means. The *Kolmogorov-Smirnov* test was carried out to assess the normality of distribution.

RESULTS AND DISCUSSION

All samples with the addition of fruit extracts showed high antioxidant activity. Chips soaked in the extract of five-flavor berries, small cranberries and goji berries were characterized by the biggest antioxidant potential. These values were higher by 77.68 and 67%, respectively, when compared to the control sample. Among the investigated apple chips, those enriched with an extract from chokeberry showed the lowest activity (Table. 1).

Table 1. Antioxidant activity, total polyphenols content and sensory evaluation of chips enriched with fruit extracts (mean ± SD)

Enrichment	Antioxidant activity [mg Trolox/100 g]	Total polyphenol content [mg catechin/100 g]	Sensory evaluation [points]
Control sample	1041 ± 42 [a]	357 ± 5 [a]	4.13 ± 0.7 [a]
Chokeberry	1504 ± 49 [b]	464 ± 18 [b]	4.08 ± 0.6 [a]
Five-flavor berry	1851 ± 102 [c]	371 ± 21 [a]	3.54 ± 0.5 [b]
Cornelian cherry	1631 ± 26 [b,c]	451 ± 28 [b,c]	3.98 ± 0.6 [a]
Woodland hawthorn	1590 ± 42 [b]	421 ± 1 [c]	4.14 ± 0.5 [a]
Goji berry	1744 ± 32 [c]	374 ± 36 [a,c]	4.18 ± 0.3 [a]
Japanese quince	1695 ± 20 [b,c]	395 ± 7 [a,c]	4.13 ± 0.7 [a]
Cranberry	1757 ± 20 [c]	387 ± 7 [a,c]	4.05 ± 0.5 [a]

The same letter, within the analyzed parameter (column) indicate no statistical significance at $p < 0.05$

Fortification has contributed to the increase in concentration of polyphenol compounds in the examined chips. The highest content of polyphenols was showed by samples soaked in chokeberry extract (about 30% higher than the control sample) and Cornelian cherry extract (28% higher), while the addition of the goji and five-flavor berry extracts had the smallest impact on total polyphenol content (only 5% higher compared to the control sample). Antioxidant activity has not always been correlated with the polyphenol content, due to the fact that the antioxidant activity is also influenced by other components of the fruit. Very high antioxidant activity of five-flavor berry extract was a consequence of the presence of many antioxidant ingredients. Lignans, catechins, anthocyanins and vitamins (C and E) have the greatest impact on the antioxidant activity of these fruits [17]. The basic groups of cranberries polyphenols are the anthocyanins (cyanidin, delphinidin and malvidin), flavones, procyanidins, flavonols (quercetin, myricetin) and hydroxycinnamic acid derivatives [5]. The chemical composition of goji berries includes a number of antioxidants, which is the cause of high ability to scavenge the free radicals. The orange color of berries comes from carotenoids (0.03-0.5% of dry matter) [2]. However, these fruits are also rich in quercetin and p-coumaric acid [1]. The antioxidant activity of chips supplemented with Japanese quince extract was about 62% higher than the control sample, while total polyphenol content in both samples were at a comparable level (Table 1). High amount of vitamin C (150 mg/100 g) and polyphenols that exhibit synergistic effects with the ascorbate, especially flavonols and procyanidins, affect the antioxidant activity of the Japanese quince [6, 16]. Chips containing the extract of Cornelian cherry were characterized, as in the case of Japanese quince, by 62% higher antiradical capacity than the control sample, but they contained only 28% more polyphenols. Cornelian cherry fruits are classified as a raw materials rich in flavonoids and anthocyanins [21, 22]. Woodland hawthorn contains more than 40 phenolic compounds, especially procyanidins, glycosides of flavonols, anthocyanins and phenolic acids [11]. As a result the antioxidant activity and the polyphenol content of chips with the addition of hawthorn extract increased by 51% and 20%, respectively, in relation to chips without enrichment. Chokeberry fruits are considered as one of the richest sources of polyphenols. Total polyphenol content of chokeberry exceed more than three times concentrations of polyphenolic compounds in other berries, such as cranberries and blackcurrants [14]. Its antioxidant activity is caused by extremely high levels of anthocyanins. However, these compounds are sensitive to high temperatures and oxygen [3]. This may explain why the chips with the addition of chokeberry extract are not characterized by the high antioxidant activity.

It should be noted that the method with the ABTS radical used to measure the antioxidant activity, permits determination both hydrophilic (vitamin C, flavonoids, anthocyanins, phenolic acids) and hydrophobic antioxidants (carotenoids, vitamin E). Accordingly, the high antioxidant activity was not always associated with the polyphenol content [10]. Furthermore, cinnamic acid derivatives are much more effective antioxidants than benzoic acid derivatives which explains the high antioxidant activity of the chips soaked in cranberry extract. Glycosylated derivatives of flavonoids have much lower antioxidant activity compared to their aglycones. This dependence can be observed in chips with the extract of five-flavor berry. It contains lignans mainly in the aglycone forms, thereby causing a high antioxidant activity [9].

Sensory analysis of chips enriched with various fruit extracts showed that almost all products received similar amount of points (3.98-4.18). Only the chips enriched with an extract of five-flavor berry have been scored lower (3.54 pts.), mainly because of the sour-bitter taste. However, among the members of the sensory panel were people who really enjoyed that flavor. All samples soaked in fruit extracts were characterized by a lower sweetness and higher acidity compared to the sample without additives. Noteworthy is also the color of enriched chips, especially with chokeberry extract. Compared to control, they have a pink color, and a sensory panel showed large dispersion in the evaluation of this feature. According to some members, color was good and desirable, while the others evaluated it as not characteristic for apple chips, decreasing the note.

CONCLUSIONS

Fruit extracts are a valuable material for fruit chips enrichment, due to their high antioxidant activity and phenolic content. However, in order to consumer approval, the final products must also be organoleptically attractive. For this reason, the best supplements for apple chips were extracts of Japanese quince fruit, goji berry and woodland hawthorn. The sample soaked in extract of five-flavor berry, despite the high antioxidant activity, was disqualified due to the very low sensory evaluation of these chips.

Conflict of interest

The authors declare no conflict of interest.

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