Mikołajczak Natalia. Phenolic compounds in dried herbs and spices commonly used in the kitchen. Journal of Education, Health and Sport. 2018;8(9):673-685 eISNN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.1413105
http://ojs.ukw.edu.pl/index.php/johs/article/view/5901

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part b item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eissn 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 02.08.2018. Revised: 18.08.2018. Accepted: 11.09.2018.

Phenolic compounds in dried herbs and spices commonly used in the kitchen

Związki fenolowe w suszonych ziołach i przyprawach powszechnie wykorzystywanych w kuchni

Natalia Mikołajczak

Chair of Plant Raw Materials Chemistry and Processing
Faculty of Food Sciences, University of Warmia and Mazury in Olsztyn

University of Warmia and Mazury in Olsztyn
Chair of Plant Raw Materials Chemistry and Processing
Pl. Cieszyński 1, 10-726 Olsztyn
e-mail: natalia.mikolajczak@uwm.edu.pl

Abstract

Introduction and aim: Currently, herbs and spices are most often used in a dried form due to low durability of raw materials. They are used to enhance or improve the taste and organoleptic properties of food, to shape the quality of food products, and also as medicines for many generations. They have antioxidant, anti-inflammatory, anti-atherosclerotic and even anti-cancer properties. These health-promoting properties result mainly from the presence of phenolic compounds. The aim of the article was to collect numerical data showing the total content of phenolic compounds and shares of individual phenolic acids and flavonoids in dried herbs and spices commonly used in the kitchen.

Brief description of the state of knowledge: The total content of phenolic compounds in dried herbs was 0.01 - 91.40 mg GAE/g d.w. A good source was bay leaf (44.40 - 46.79 mg GAE/g d.w.) and oregano (91.40 mg GAE/g d.w.). However, the content of phenolic compounds in dried spices was in the range of 0.02 - 155.10 mg GAE/g d.w., the dominant amounts contained cinnamon. Small amounts (0.01 - 0.28 mg GAE/g d.w.) of phenolic compounds were found in dried herbs such as lovage, rosemary, lemond bald, sage, and in case of dried species only in turmeric. The shares of phenolic acids in dried herbs were in the range 0.01 (caraway) - 5.17 (thyme) mg/g d.w. for caffeic acid, 0.001 (caraway) - 0.91 (thyme) mg/g d.w. for ferulic acid, 0.01 (caraway) - 0.26 (fennel) mg/g d.w. for chlorogenic acid, and 0.96 (oregano) - 1.64 (lovage) mg/g d.w. for neochlorogenic acid. In the case of dried spices, the shares of individual phenolic acids were 0.01 (ginger) - 0.18 (turmeric) mg/g d.w. for ferulic acid, 0.02 (star anise) - 0.10 (cinnamon) mg/g d.w. for p-coumaric acid, and 0.06 (nutmeg) - 0.21 (star anise) mg/g d.w. for protocatechuic acid. The content of flavonoids in dried herbs and spices was small. A valuable source of luteolin was rosemary (6.16 mg/g d.w.), quercetin was lovage (9.23 mg/g d.w.) and apigenin was rosemary (0.44 mg/g d.w.) and fennel (0.62 mg/g d.w.). Dried spices contained only catechin (curry) and rutin (star anise).

Summary: Based on the review of available literature, it can be concluded that dried herbs (bay leaf and oregano) and spices (cinnamon and turmeric) are a good source of phenolic compounds. In addition, dried herbs (oregano, thyme, fennel, lovage) are characterized by the presence of such phenolic acids as caffeic, chlorogenic, and ferulic, while dried spices (cinnamon, star anise) are a source of p-coumaric, protocatechuic and chlorogenic acids. The share of flavonoids in the dried herbs and spices is varied, however dried spices (ginger, cinnamon) contain small amounts of flavonoids.

Key words: phenolic compounds, phenolic acids, flavonoids, dried herbs, dried spices

Introduction

Culinary herbs and spices are vegetable products, which are obtained from such parts of plants as fruits (mustard, fennel), rhizomes, roots (turmeric, ginger), leaves (marjoram, thyme, sage), barks (cinnamon), floral parts (cloves), bulbs (garlic, onion), or stems (coriander) [22]. They have been used in the kitchen for a very long time, not only as preservatives to extend the shelf life of food, but also to enhance or improve the taste and organoleptic properties of different

foods due to their sensory [8, 13]. Herbs and spices are also used for health purposes. In India, they were considered traditional medicine, e.g. turmeric was used in people with jaundice, basil to protect the heart, and ginger to ease nausea and indigestion [23].

Fresh herbal and spicy raw materials are unstable due to the high water content, destructive properties also show enzymes contained in them. All this makes it especially important to extend the durability of these valuable raw materials [21]. In addition, a significant increase in the development of various technologies enabling long-term storage of durable products has increased the interest in herbs and spices in the dried form [11, 12]. Both natural methods (in the open spaces and in enclosed spaces), using the heat of solar radiation and the heat contained in the air, as well as thermal, mainly convection drying, are used. Less frequent use is lyophilization, dielectric and radiant drying method [7]. However, the lyophilization method is mainly used in the food industry [9, 16], which uses herbs and spices due to the previously mentioned spoilage-reducing properties. They ensure greater stability of manufactured food products, e.g. they counteract the oxidation of oils, fats in meat and dairy products [23].

Recent studies show that the use of herbs and spices has a beneficial effect on human health. They contain significant amounts of vitamins (C, E), carotenoids, anthocyanins and phytoestrogens [27]. Herbs and spices are also a valuable source of phenolic compounds [26], which have protective properties of important cellular components such as DNA, proteins and lipid membranes due to the ability to counteract reactive oxygen forms [20]. Phenolic compounds also have redox properties, which may result from several mechanisms: free radical absorption capacity, chelating activity for transition metals and (or) singlet oxygen reduction [17]. In addition to antioxidant activity, herbs and spices have antifungal, antibacterial, anti-inflammatory, anti-atherosclerotic, and even anti-cancer properties [27, 18]. They can also stimulate appetite, contribute to the increase of the amount of gastric juice secretion and inhibit the oxidation processes in the human body [15].

Many culinary herbs and spices are a common source of phenolic compounds that have been reported to have a higher antioxidant capacity for grains, nuts and fruits [3]. In this article were collected literature data, which aim to present the content of phenolic compounds (total content, as well as content of individual phenolic acids and flavonoids) in dried herbs and spices commonly used in the kitchen.

Dried herbs

The content of phenolic compounds in dried herbs was presented in Table 1. The values were in the range of 0.01 - 91.40 mg GAE (Gallic Acid Equivalent)/g d.w. (dry weight), and depended on the type of herb.

The highest content of phenolic compounds was characterized by air-dried oregano (91.40 mg GAE/g d.w.). A high content of these compounds was also found for bay leaf, in which the total content of phenolic compounds was 44.40 - 46.79 mg GAE/g d.w. In dried herbs such as marjoram, Greek oregano, sage, and also in basil, the content of phenolic compounds was 27.70, 27.00, 24.30 and 26.50 mg GAE/g d.w., respectively. Slightly lower content of these compounds was found for basil compatto, lovage and parsley leaves. In these herbs, the content of phenolic compounds was almost 78-86% lower compared to air-dried oregano.

The content of phenolic compounds in the other 20 herbs did not exceed 10 mg (phenolic compounds) per 1 g d.w. The values were within 2.50 (pimento) – 9.00 (caraway) mg GAE/g d.w. In addition, as many as 10 herbs such as basil (originating in Malaysia), lemon balm, mint and sage as well as dill, marjoram, lovage, rosemary were characterized by a very low content of total phenolic compounds. The content of these compounds was lower by over 98% compared to the air-dried oregano and did not exceed 1 mg per 1 g d.w.

Tab. 1. Total content of phenolic compounds in dried herbs.

Dried herbs	Total phenolic compounds content [mg GAE/g d.w.]	Reference
Bay leaf	46.79	[10]
Bay leaf	44.40	[19]
Basil	0.45	[4]
Basil	26.50	[19]
Basil compatto	20.30	[5]
Caraway	9.00	[10]
Caraway	3.99	[24]
Dill	0.94	[24]
Fennel	6.76	[10]
Greek oregano	27.00	[5]
Lemon bald	0.13	[26]
Lemon bald	0.49	[2]
Lovage	19.70	[5]
Lovage	0.01	[26]
Lovage	17.80	[19]
Marjoram	0.96	[24]
Marjoram	27.70	[5]
Marjoram	8.28	[4]
Mint	0.45	[2]
Oregano	91.40	[5]
Oregano	8.91	[4]
Parsley leaves	13.60	[19]
Pimento	2.50	[19]
Rosemary	0.02	[26]
Rosemary	7.49	[4]
Sage	0.08	[4]
Sage	3.18	[4]
Sage	24.30	[5]
Sage	0.28	[2]
Spearmint	2.69	[4]
Thyme	4.52	[4]

As shown in the Table 1, literature references give different total phenolic compounds content in the same types of dried herbs. The most divergent results were found for rosemary as well as sage. Differences between the phenolic compounds content were over 98%, which clearly indicates a significant discrepancy between the individual results. Other differences between the phenolic compounds content in the same type of dried herbs (basil, lovage, marjoram, oregano) were equally high and ranged from 70 to more than 96%.

In contrast to the above-mentioned dried herbs, the total phenolic compounds in such dried herbs as bay leaf and lovage was not significant. Bay leaf contained phenolic compounds in amount of 46.79 [10] - 44.40 [19] mg GAE/g d.w., while lovage 17.80 [19] -19.70 [5] mg GAE/g d.w.

Phenolic acids content

Research conducted by Wojdyło et al. [26] showed that lyophilized herbs are a source of caffeic and ferulic acids [Tab. 2]. Oregano (6.49 mg/g d.w.), thyme (5.17 mg/g d.w.) and rosemary (4.06 mg/g d.w.) were the highest share of caffeic acid. Lovage also contained a significant amount of caffeic acid, less by 40% compared to the share of this acid in oregano. The ferulic acid share was in the range of 0.36 – 0.91 mg/g d.w. Its highest amounts were found in thyme (0.91 mg/g d.w.) and lovage (0.76 mg/g d.w.). No ferulic acid was found in oregano. Neochlorogenic acid was present in lovage and oregano, their share was 1.64 and 0.96 mg/g d.w., respectively. However, the presence of p-coumaric acid was not confirmed in any of these lyophilized herbs.

Tab. 2. Content of individual phenolic acids in lyophilized herbs according to the Wojdyło et al. [26] research.

Dried herbs	Phenolic acids [mg/g d.w.]			
	caffeic acid	ferulic acid	neochlorogenic acid	p-coumaric acid
Lovage	3.90	0.76	1.64	n.d.
Oregano	6.49	n.d.	0.96	n.d.
Rosemary	4.06	0.36	n.d.	n.d.
Thyme	5.17	0.91	n.d.	n.d.

n.d. - not detected

Lu et al. [10] found in the lyophilized caraway such phenolic acids as chlorogenic (0.09 mg/g d.w.) and ferulic (0.02 mg/g d.w.). In addition, 0.03 mg/g d.w. of phenolic compounds have not been identified. According to these studies, the rich source of chlorogenic acid was lyophilized fennel (0.26 mg/g d.w.). In significant amounts in lyophilized bay leaf (474.10 mg CAE (Chlorogenic Acid Equivalent)/g d.w.) and lyophilized fennel (590.40 mg CAE/g d.w.) were

found other phenolic acids, which the authors were unable to identify. No protocatechuic, caffeic and p-coumaric acids were found in these lyophilized herbs [Tab.3].

Tab. 3. Content of individual phenolic acids in lyophilized herbs according to the Lu et al. [10] research.

Dried herbs	Phenolic acids [mg/g d.w.]					
	caffeic acid	chlorogenic acid	ferulic acid	p-coumaric acid	protocatechuic acid	other*
Bay leaf	n.d.	n.d.	n.d.	n.d.	n.d.	474.10
Caraway	n.d.	0.09	0.002	n.d.	n.d.	29.30
Fennel	n.d.	0.26	n.d.	n.d.	n.d.	590.40

*The total amounts of unkown phenolic acids were expressed as mg CAE (Chlorogenic Acid Equivalent)/g d.w., n.d. - not detected

Vallverdú-Queralt et al. [24] analyzed dried herbs that originated from the Netherlands. Based on the obtained results, they found that in dried caraway were the phenolic acids such as chlorogenic acid (0.014 mg/g d.w.), caffeic acid (0.01 mg/g d.w.), p-coumaric acid (0.011 mg/g d.w.) and ferulic acid (0.001 mg/g d.w.). According to these studies, dried marjoram contained ferulic acid (0.003 mg/g d.w.) and syringic acid (0.005 mg/g d.w.). Chlorogenic acid was found in amount of 0.02 mg/g d.w. in dried dill, which additionally had a low content of ferulic acid (0.002 mg/g d.w.).

Proestos et al. [14] found that in Greek dried caraway the content of caffeic and ferulic acids was 0.05 and 0.06 mg/g d.w., respectively. In addition, they also found the presence of gallic acid in the amount of only 0.01 mg/g d.w.

Flavonoids content

Wojdyło et al. [26] found that the dominant flavonoid in lyophilized lovage was quercetin, in the amount of 9.23 mg/g d.w. Whereas, lyophilized rosemary contained significant amounts of luteolin (6.16 mg/g d.w.) and apigenin (0.44 mg/g d.w.). Lyophilized oregano and thyme did not contain quercetin, luteolin and apigenin. In addition, all of the cited herbs did not contain kaempferol, isorhamnetin and myricetin [Tab. 4].

Tab. 4. Content of individual flavonoids in lyophilized herbs to the Wojdyło et al. [26] research.

Dried herbs	Flavonoids [mg/g d.w.]					
	apigenin	isorhamnetin	kaempferol	luteolin	myricetin	quercetin
Lovage	n.d.	n.d.	n.d.	n.d.	n.d.	9.23
Oregano	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Rosemary	0.44	n.d.	n.d.	6.16	n.d.	n.d.
Thyme	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

n.d. - not detected

According to research conducted by Lu et al. [10], lyophilized fennel contained apigenin in the amount of 0.62 mg/g d.w., while the share of rutin was found almost 16-fold lower. In

these research, it was shown that lyophilized caraway contained luteolin in the amount of 0.06 mg/g d.w. In addition, lyophilized herbs contained significant amounts of other phenolic compounds defined by the authors as 'unknown'. Their content was in lyophilized bay leaf was 2138.20 mg RE (Rutin Equivalent)/g d.w., in caraway 2719.40 mg RE/g d.w., while in fennel was only 141.60 mg RE/g d.w. In bay leaf (other than the unidentified), no flavonoids were found. Bay leaf, caraway and fennel also did not contain other flavonoids such as quercetin, galangal and catechin [Tab. 5].

Tab. 5. Content of individual flavonoids in lyophilized herbs according to the Lu et al. [10] research.

Dried herbs	Flavonoids [mg/g d.w.]						
	apigenin	catechin	galangal	luteolin	quercetin	rutin	other*
Bay leaf	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2138.20
Caraway	n.d.	n.d.	n.d.	0.06	n.d.	n.d.	2719.40
Fennel	0.62	n.d.	n.d.	n.d.	n.d.	0.04	141.60

*The total amounts of unkown flavonoids were expressed as mg RE (Rutin Equivalent)/g d.w., n.d. - not detected

In Vallverdú-Queralt et al. [24] research, catechin and epicatechin were identified in dried caraway from the Netherlands. The content of these compounds was 0.01 mg/g d.w. for catechin and 0.006 mg/g d.w. for epicatechin.

Proestos et al. [14] found that Greek dried oregano contained quercetin in the amount of 0.01 mg/g d.w. Whereas, in dried caraway the authors found the presence of luteolin in the amount of 0.03 mg/g d.w. and eriodictyol in the amount of 0.003 mg/g d.w., but such flavonoids as quercetin, rutin and apigenin were not detected.

Dried spices

The content of phenolic compounds, in dried spices was presented in Table 6. The content of these bioactive compounds was in the range of 0.02 - 155.10 mg GAE/g d.w., and similar to dried herbs, phenolic compounds content depended on the type of spice.

Analysis of the content of phenolic compounds in dried herbs showed that significant amounts (and thus valuable source) contained cinnamon (155.10 mg GAE/g d.w.). However, the second cinnamon (originating in China) contained 30% less of these compounds. A similar content of phenolic compounds (to Chinese cinnamon) was found for turmeric (42.90 mg GAE/g d.w.). Dried spices such as nutmeg, star anise, as well as ginger contained phenolic compounds in amounts of 18.23, 14.94 and 14.50 mg GAE/g d.w., respectively.

The content of phenolic compounds in 14 dried spices did not exceed 10 mg (phenolic compounds) per 1 g d.w. Their total content in these spices was in the range 0.02 - 0.63 mg GAE/g d.w. The highest content of phenolic compounds was characterized by spices such as chilli pepper and ginger, which was 9.30 and 9.20 mg GAE/g d.w., respectively. Equally high content was noted for black pepper, star anise and nutmeg. The content of phenolic compounds in them was lower by almost 95% compared to the cinnamon (155.10 mg GAE/g d.w.). Whereas, turmeric were characterized by a low content of phenolic compounds, which was only 0.02 - 0.63 mg GAE/g d.w.

Tab. 6. Total content of phenolic compounds in dried spices.

Dried spices	Total phenolic compounds content [mg GAE/g d.w.]	Reference
Black pepper	6.40 mg	[19]
Cardamon	2.20 mg	[19]
Chili pepper	9.30 mg	[10]
Chili pepper	7.10 mg	[19]
Cinnamon	45.24 mg	[10]
Cinnamon	155.10 mg	[19]
Curry	8.28 mg	[10]
Garlic	2.00 mg	[19]
Ginger	9.20 mg	[10]
Ginger	14.50 mg	[19]
Nutmeg	0.63 mg	[24]
Nutmeg	18.23 mg	[10]
Nutmeg	6.30 mg	[19]
Star anise	14.94 mg	[10]
Star anise	7.40 mg	[19]
Turmeric	0.43 mg	[24]
Turmeric	0.02 mg	[26]
Turmeric	42.90 mg	[19]
White pepper	3.53 mg	[10]

The most diverse results of the phenolic compounds content were reported for turmeric. Differences in content for individual literature references were over 95%. Equally high differences were noted for nutmeg (almost 93 and 97%). Other differences between the phenolic compounds content in the same type of dried spices (cinnamon, ginger, star anise) ranged from 44 to 71%.

The most similar to each other were the content of phenolic compounds for chili pepper, they were 7.10 [19] and 9.30 [10] mg GAE/g d.w., respectively.

Phenolic acids content

The major phenolic acid found in lyophilized spices such as cinnamon, nutmeg and turmeric was p-coumaric acid [Tab. 7]. Its highest amount was found in cinnamon (0.10 mg/g d.w.), other spices were characterized by 50% (nutmeg) and 40% (turmeric) lower its amount

compared to cinnamon. Ferulic acid was identified only in turmeric in an amount of 0.18 mg/g d.w. No caffeic and neochlorogenic acid were found in these lyophilized spices.

Tab. 7. Content of individual phenolic acid in lyophilized spices to the Wojdyło et al. [26] research.

Dried spices	Phenolic acids [mg/g d.w.]			
	caffeic acid	ferulic acid	neochlorogenic acid	p-coumaric acid
Cinnamon	n.d.	n.d.	n.d.	0.10
Nutmeg	n.d.	n.d.	n.d.	0.05
Turmeric	n.d.	0.18	n.d.	0.06

n.d. - not detected

Analyzes carried out by Lu et al. [10] showed that lyophilized chili pepper contained phenolic acids such as p-coumaric (0.05 mg/g d.w.) and ferulic (0.02 mg/g d.w.) [Tab. 8]. The share of ferulic acid was also found in lyophilized curry in an amount similar to the chili pepper and in lyophilized ginger, which was characterized by its lowest amount (2-fold compared to chilli pepper). Lyophilized cinnamon was a good source of chlorogenic acid, its amount was 0.19 mg/g d.w. The authors also distinguished the content of other acids in cinnamon whose names have not been identified. Their sum was 839.30 mg CAE/g d.w. Protocatechuic acid was found in lyophilized nutmeg (0.06 mg/g d.w.) and lyophilized star anise (0.21 mg/g d.w.). In addition, star anise also contained p-coumaric acid, in amount of 0.02 mg/g d.w. No caffeic acid was found in these lyophilized herbs.

Tab. 8. Content of individual phenolic acids in lyophilized spices according to the Lu et al. [10] research.

Dried herbs		Phenolic acids [mg/g d.w.]				
	caffeic acid	protocatechuic acid	p-coumaric acid	chlorogenic acid	ferulic acid	other*
Chili pepper	n.d.	n.d.	0.05	n.d.	0.02	n.d.
Cinnamon	n.d.	n.d.	n.d.	0.19	n.d.	839.30
Curry	n.d.	n.d.	n.d.	n.d.	0.02	n.d.
Ginger	n.d.	n.d.	n.d.	n.d.	0.01	n.d.
Nutmeg	n.d.	0.06	n.d.	n.d.	n.d.	n.d.
Star anise	n.d.	0.21	0.02	n.d.	n.d.	n.d.

*The total amounts of unkown phenolic acids were expressed as mg CAE (Chlorogenic Acid Equivalent)/g d.w., n.d. - not detected

Research of Vallverdú-Queralt et al. [24] showed that dried nutmeg from the Netherlands contained caffeic, protocatechuic, rosmarinic, and p-hydroxybenzoic acids. Their amounts were 0.16, 0.001, 0.001, and 0.003 mg/g d.w., respectively.

Flavonoids content

Lu et al. [10] reported that Chinese lyophilized herbs such as cinnamon and ginger did not contain any flavonoids. In lyophilized chili pepper only the presence of other flavonoids in the amount of 283 mg RE/g d.w. was found, the authors would not be able to recognize their individual names. Lyophilized nutmeg and lyophilized star anise contained rutin. Its concentration in star anise was 0.25 mg/g d.w., but in nutmeg the content was more than 8-fold lower. Both of these lyophilized herbs also contained significant amounts of 'unknown' flavonoids; 117.60 (nutmeg) and 463.30 (star anise) mg RE/g d.w. The analysis of flavonoids content in lyophilized curry showed significant amounts of catechin (0.11 mg/g d.w.) and 'unknown' flavonoids (2462.60 mg RE/g d.w.). These lyophilized herbs also did not contain such flavonoids as apigenin, luteolin, quercetin and naringin [Tab. 9].

Tab. 9. Content of individual flavonoids in lyophilized herbs according to the Lu et al. [10] research.

Dried herbs	Flavonoids [mg/g d.w.]							
	apigenin	catechin	galangal	luteolin	naringin	quercetin	rutin	other*
Chili pepper	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	283.50
Cinnamon	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Curry	n.d.	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	2462.60
Ginger	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Nutmeg	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	1170.60
Star anise	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.25	463.30

*The total amounts of unkown flavonoids were expressed as mg RE (Rutin Equivalent)/g d.w., n.d. - not detected

Diversity in the chemical composition of dried herbs and spices depends on many factors, e.g. environmental growth factors (temperature, soil, light), harvest time, storage conditions [25]. In addition, significant changes in the content of phenolic compounds cause drying process. The negative influence of the elevated temperature during convection drying was confirmed by Arslan et al. [1]. Similarly, Jałoszyński et al. [6] research shown that microwave-vacuum (at microwave power of 240, 360 and 480 W) and convection (at 50, 60 and 70°C) methods were caused by the degradation of phenolic compounds as the temperature of drying increased. However, Arslan et al. [1] reported that the use of natural (20-30°C) and microwave drying (700 W) caused an increase in the content of phenolic compounds. The authors explain this

phenomenon as the release of phenolic antioxidants from the matrix as a result of a structural violation (during drying), which consequently contributes to the increase in the level of phenols. Differences between levels in the content of phenolic compounds in dried herbs and spices may also result from genotypic differentiation, selection of tested plant parts, sampling and determination methods [24].

Summary

Based on the review of available literature, it can be concluded that dried herbs and spices are generally a good source of phenolic compounds, wherein the content of these bioactive compounds depends mainly on the type of herb. In particular, dried herbs such as bay leaf and oregano, as well as dried spices such as cinnamon and turmeric, contain significant amounts of phenolic compounds (42.90 - 155.10 mg GAE/g d.w.). However, small amounts (0.01 - 0.45 mg GAE/g d.w.) are found in lovage, rosemary, lemon balm, sage, basil (herbs), and turmeric (spices).

The analysis of the share of individual phenolic acids has shown that the dried herbs contain significant amounts of such acids as caffeic (oregano, thyme, rosemary), neochlorogenic (lovage, oregano), and ferulic (thyme, lovage). In addition, the source of chlorogenic acid is dried fennel, whereas acids such as p-coumaric and protocatechuic are absent (or present in trace amounts) in dried herbs. Dried spices are a source of p-coumaric (cinnamon), protocatechuic (star anise), and chlorogenic (cinnamon) acids. They also contain small amounts of p-coumaric acid (chili pepper, star anise) and ferulic (turmeric, chili pepper, ginger). In dried spices, neochlorogenic and caffeic (except for nutmeg) acids are not found.

The content of flavonoids in dried herbs and spices is varied. In dried herbs, flavonoids such as apigenin (rosemary, fennel), luteolin (rosemary) and quercetin (lovage) are found. However, dried spices contain small amounts of flavonoids, only catechin occurs in the curry, and the star anise is the source of rutin.

References:

1. Arslan D, Özcan MM, Okyay Mengeş H. Evaluation of drying methods with respect to drying parameters, some nutritional and colour characteristics of peppermint (*Mentha* x *piperita* L.). Energy Convers Manag. 2010; 51:2769–2775.
2. Atanassova M, Georgieva S, Ivancheva K. Total phenolic and total flavonoid contents, antioxidant capacity and biological contaminants in medicinal herbs. J Univ Chem Technol Metallurgy. 2011; 46(1):81–88.
3. Carlsen MH, Halvorsen BL, Holte K, Bohn SK, Dragland S, Sampson L, Willey C, Senoo H, Umezono Y, Sanada C, Barikmo I, Berhe N, Willett WC, Phillips KM, Jacobs DR Jr, Blomhoff R. The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. Nutr J. 2010; 9(3):1−11.
4. Chan EWC, Kong LQ, Yee KY, Chua WY, Loo TY. Antioxidant and antibacterial properties of some fresh and dried *Labiatae* herbs. Free Radicals and Antioxidants. 2012; 2(3):20–27.
5. Chrpová D, Kouřimská L, Gordon MH, Heřmanová V, Roubíčková I, Pánek J. Antioxidant activity of selected phenols and herbs used in diets for medical conditions. Czech J Food Sci. 2010; 28:317–325.
6. Jałoszyński K, Figiel A, Wojdyło A. Drying kinetics and antioxidant activity of oregano. Acta Agrophys. 208; 11:81–90.
7. Karwowska K, Przybył J. Suszarnictwo i przetwórstwo ziół. Wydawnictwo SGGW. Warszawa. 2005.
8. Kivilompolo M, Obůrka V, Hyötyläinen T. Comparison of GC-MS and LC-MS methods for the analysis of antioxidant phenolic acids in herbs. Anal Bioanal Chem. 2007; 388(4):881- 887.
9. Kmiecik W, Lisiewska Z, Jaworska G. Effect of biological and agrotechnical factors on the chemical composition of dill (*Anethum graveolens* L.). El J Pol Agri Univ. Food Sci Technol. 2002; 5(1):11.
10. Lu M, Yuan B, Zeng M, Chen J. Antioxidant capacity and major phenolic compounds of spices commonly consumed in China. Food Res Int. 2011; 44:530–536.
11. Mitek M, Grasik A. Polifenole w żywności, zawartość polifenoli. Przemysł Spożywczy. 2007; 9:38–39.
12. Mitek M, Grasik A. Polifenole w żywności. Wpływ na cechy organoleptyczne żywności. Przemysł Spożywczy. 2009; 5:34–35.
13. Park JB. Identification and quantification of a major anti-oxidant and anti-inflammatory phenolic compound found in basil, lemon thyme, mint, oregano, rosemary, sage, and thyme. Int J Food Sci Nutr. 2011; 62(6):577–584.
14. Proestos C, Boziaris IS, Nychas G-JE, Komaitis M. Analysis of flavonoids and phenolic acids in Greek aromatic plants: Investigation of their antioxidant capacity and antimicrobial activity. Food Chem. 2006; 95:664–671.
15. Remiszewski M, Kulczak M, Jeżewska M, Korbas E, Czajkowska D. Wpływ procesu dekontaminacji z zastosowaniem pary wodnej na jakość wybranych przypraw. Zywn-Nauk Technol Ja. 2006; 3(48):23–34.
16. Sang-Hee O, Dai-Eun S, Kun-Jong L, Mee-Ree K. Heat processing of edible plants grown in Korea has differential effects on their antioxidant capacity in bovine brain homogenate. Nutraceuticals and Food. 2002; 7(4):378–385.
17. Shan B, Cai YZ, Sun M, Corke H. Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents. J Agr Food Chem. 2005; 53:7749–7759.

18. Shobana S, Naidu KA. Antioxidant activity of selected Indian spices. Prostaglandins Leukot Essent Fatty Acids. 2000; 62(2):107–110.

19. Słowianek M, Leszczyńska J. Antioxidant properties of selected culinary spices. Herba Pol. 2016; 62(1):29–41.

20. Su L, Yin J-J, Charles D, Zhou K. Total phenolic contents, chelating capacities, and venging properties of black peppercorn, nutmeg, rosehip, cinnamon and oregano leaf. Food Chem. 2007; 100:990–997.

21. Śledź M, Witrowa-Rajchert D. Składniki biologicznie czynne w suszonych ziołach – czy ciągle aktywne?. Kosmos. 2012; 61(2):319–329.

22. Tajkarimi MM, Ibeahim SA, Cliver DO. Antimicrobial herb and spice compounds in food. Food Control. 2010; 21:119–1218.

23. Tapsell LC, Hemphill I, Cobiac L, Sullivan DR, Fenech M, Patch CS, Roodenrys S, Keogh JB, Clifton PM, Williams PG. Health benefits of herbs and spices: the past, the present, the future. Med J Australia. 2006; 185(4):1–24.

24. Vallverdú-Queralt A, Regueiro J, Alvarenga JFR, Martinez-HuelamoM, Leal LN, Lamuela-Raventos RM. Characterization of the phenolic and antioxidant profiles of selected culinary herbs and spices: caraway, turmeric, dill, marjoram and nutmeg. Food Sci Technol. 2015; 35(1):189–195.

25. Wang SY. Antioxidant capacity of berry crops, culinary herbs and medicinal herbs. Acta Hortic. 2003; 620:461–472.

26. Wojdyło A. Oszmiański J. Czemerys R. Antioxidant activity and phenolic compounds in 32 selected herbs. Food Chem. 2007; 105:940–949.

27. Zych I, Krzepiłko A. Pomiar całkowitej zdolności antyoksydacyjnej wybranych antyoksydantów i naparów metodą redukcji rodnika DPPH. Chemia. Dydaktyka. Ekologia. Metrologia. 2010; 15(1):51–54.