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THE INFLUENCE OF COOKING ON NUTRITIONAL AND FUNCTIONAL COMPOUNDS CONTENT IN POTATO TUBERS®

Wpływ gotowania na zawartość odżywczych i funkcjonalnych składników w bulwach ziemniaka®

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Key words: potatoes, antioxidants, dietary fiber, polyphenols, thermal processing.

Potatoes are good source of phenolic compounds and vitamin C. Unfortunately during processing level of these compounds is lowered. Therefore it is so important to evaluate the influence of processing (cooking) on content of health–promoting compounds in potatoes. The potato tubers were peeled and cooked. The level of nutritional compounds, dietary fiber, vitamin C, total phenolic content (TPC), flavonoids and antioxidative activity were measured in raw and cooked potatoes. Cooking process of potatoes leaded to decrease in the content of proteins, lipids, starch, ash and total, insoluble dietary fiber. A loss of vitamin C, as well as polyphenols and flavonoids also was observed, that resulted in a decrease of antioxidant activity. Cooking process reduced the nutrients content, mainly starch and mineral compounds.

Słowa kluczowe: ziemniaki, przeciwutleniacze, błonnik pokarmowy, polifenole, gotowanie.

Ziemniaki są dobrym źródłem witaminy C oraz polifenoli. Niestety podczas ich przetwarzania zawartość tych składników spada. Ważne jest zatem określenie wpływu gotowania na zawartość składników prozdrowotnych w ziemniakach. Bulwy ziemniaka przed ugotowaniem obrano. W ziemniakach surowych oraz poddanych gotowaniu określono poziom składników odżywczych, błonnika pokarmowego, witaminy C, zawartość polifenoli ogółem, flawonoidów oraz aktywność antyoksydacyjną. Proces gotowania ziemniaków spowodował zmniejszenie zawartości białka, tłuszczy, skrobi, popiołu oraz błonnika nierozpuszczalnego. Zaobserwowano także utratę witaminy C, polifenoli i flawonoidów, co skutkowało obniżeniem aktywności antyoksydacyjnej. Gotowanie zmniejszyło zawartość składników odżywczych, głównie skrobi i składników mineralnych.

INTRODUCTION

Potato is one of the most important crops in the world (5th place after sugar cane, corn, rice and wheat), and plays a vital role in human nutrition [4]. Popularity of cooked potato consumption in Poland, and other countries, is based rather on eating habits, than deep nutritional knowledge and awareness of dietary benefits. Potato tubers are good source of phenolic compounds like chlorogenic, caffeic, ferulic or protocatechuic acids [1, 11, 23, 30, 31], as well as flavonoids, which together with carotenoids are responsible for potato skin and flesh color [16, 17]. Phenolic compounds reveal antimicrobial, antiviral and also anticancerogenic activity [6, 9] and together with vitamin C they also exhibit health-promoting properties by decreasing the risk of heart diseases and tumors occurrence [22].

Unfortunately during industrial processing or home cooking, many of these compounds are lost. For that reason, it is very important to evaluate the influence of processing on content of health–promoting compounds in potato tubers.

The aim of present work was to investigate the influence of cooking on level of nutritional compounds, like protein, starch, lipid and mineral compounds and health-promoting compounds (dietary fiber, polyphenols, vitamin C) in potato tubers. Also antioxidant activity of polyphenols was evaluated.

MATERIAL AND METHODS

Materials

Three different varieties of potatoes were used in this research. *Raja* (RA) variety was provided by Agrico Poland

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Ltd, *Rosalind* (RO) by Europlant Ltd. and *Courage* (C) by HZPC Poland Ltd. The potatoes were stored in the dark at temperature 4–8 °C for a maximum of two days before testing. The tubers were peeled using a knife. Potato tubers were cooked in boiling water for 25 min.

In the description of Tables and Figures the following abbreviations were used: *Raja* - RA, *Rosalind* - RO and *Courage* – C. Samples before cooking (raw potatoes) were denoted as _r, and after cooking as _c, ie. RA_r - stands for raw (uncooked) potatoes of *Raja* variety.

Methods

The analysis of nutritional compounds included: proteins, lipids, mineral compounds and dietary fiber (soluble and insoluble fraction) according to AOAC [2], and starch according ICC [13]. Total phenolic content (TPC) was assayed according to Singleton et al. [29] using Helios gamma 100-240 spectrophotometer. Results were expressed as mg catechin g^{-1} of dry matter of product. Flavonoids content was measured according to Oomah et al. [25] using Helios gamma 100-240 spectrophotometer. Results were expressed as mg rutin g^{-1} of dry matter of product. Vitamin C content was measured according ISO standard [15] using Tillmann's reagent. Antioxidant activity was measured by FRAP method (Ferric Reducing Ability of Plasma) according to Benzie and Strain [3], and by $ABTS^{\bullet+}$ radical cation decolorization assay [26].

Statistical analysis

All experiments were performed in triplicate and results were expressed as their mean±SD. ANOVA was performed by means of Statistica software (Stat Soft, Tulsa, OK, USA). Differences among samples were calculated by Duncan's test, $p > 0.05$.

Results and discussion

Potato tubers before consumption are subjected to culinary processing in order to obtain desirable sensory features and to improve their texture, digestibility and assimilation of nutrients. Such operations change their chemical composition and nutritional value [19].

Before tubers are cooked they are subjected to pre-processing, including cleaning and peeling, causing considerable losses of vitamins and mineral constituents. But thermal treatment has far more important influence on composition and nutritional value. Intensity and extent of changes depend on applied temperature and time of operation [19].

Chemical composition of potato tubers is given in Table 1. It was observed, that protein content in tubers of *Raja* variety did not change after cooking when compared to raw material. Reverse situation took place in case of two other varieties (*Rosalind, Courage*), where protein content diminished about 2%. Decrease in protein content can be related to the presence of non-protein nitrogen, which is water soluble, and consequently washed-out. Another, constituent are lipids, present in small amounts which accounts to caloric value of potatoes, especially when compared to cereals [19]. On the other hand potato lipids are extremely valuable, due to presence of essential fatty acids (EFA), like linolenic and linoleic [12]. Lipids content, independently of potatoes variety, was lowered after cooking by 5.4 – 13.4% when compared to fresh tubers. Lipids are quite susceptible to high temperature, being subjected to oxidation, and as a result their amount was going down. But due to initial, rather small, content the effect of cooking could be negligible.

Mineral substances content generally did not undergo changes during processing. But due to fact, that their content is the highest in outer part of tuber they were removed during peeling [34]. In present research, no changes were discovered in *Raja* variety tubers in mineral compounds content before and after cooking. It was in opposition to two other varieties, where it was lowered after cooking by 8% and 18% in *Rosalind* and *Courage* respectively (Table 1).

Cooking had also detrimental effect on the main component of potato tubers - starch. In all investigated varieties of potatoes (Table 1) starch level was reduced by about 20%, that can be attributed to starch loss from cells damaged during processing. But consumption of potatoes is only possible after thermal treatment, when starch undergoes pasting that enables its digestibility [5].

Tabela 1. Skład chemiczny badanych ziemniaków przed i po ugotowaniu

Table 1. Chemical composition of investigated potatoes before and after cooking

Sample	Starch [g·100g^{-1}]	Protein [g·100g^{-1} d.m.]	Lipids [g·100g^{-1} d.m.]	Dietary fiber [g·100g^{-1} d.m.]			
				Insoluble	Soluble	Total	Mineral compounds
RA_r	8.87±0.05^{d}*	9.37±0.03^{c}	3.12±0.00^{e}	7.84±0.24^{e}	2.46±0.10^{b}	10.30±0.23^{f}	3.95±0.04^{a}
RA_c	7.12±0.27^{a}	9.40±0.01^{c}	2.95±0.05^{d}	5.26±0.32^{b}	3.65 ± 0^{c}	8.91±0.18^{c}	3.87±0.05^{a}
RO_r	10.62±0.14^{f}	9.29±0.00^{b}	1.19±0.02^{c}	7.21±0.00^{d}	2.52±0.08^{b}	9.73±0.16^{e}	4.58±0.07^{c}
RO_c	8.57±0.17^{c}	9.09±0.07^{a}	1.03±0.05^{b}	4.67±0.12^{a}	2.20±0.02^{a}	6.87±0.13^{a}	4.22±0.15^{b}
C_r	10.35± 0.06^{e}	9.45±0.00^{d}	0.98±0.02^{b}	6.88±0.11^{c}	2.47±0^{b}	9.35±0.14^{d}	4.71±0.01^{d}
C_c	8.19± 0.10^{b}	9.24±0.05^{b}	0.87±0.04^{a}	4.57±0.17^{a}	2.57± 0.11^{b}	7.14± 0.07^{b}	3.85±0.19^{ab}

*different letters in column denote mean values that statistically differ one from another (Duncan's test, at p=0.05)

Źródło: Badania własne

Source: The own study

Non-starch polysaccharides are quite important component, present in potato tubers, contributing to dietary fiber, especially to its soluble fraction. They have powerful hypocholesterolemic and hypoglycemic properties [10]. Thermal treatment caused losses in insoluble fiber fraction reaching 30% in all investigated varieties of potatoes, and total dietary fiber level was reduced by 13.5 – 30%, when compared to non-processed potatoes (Table 1). This fact could be explained by dietary fiber hydrolysis occurring during culinary processing, and for that reason much lower level of this compound was observed in processed potatoes than in raw samples.

After cooking of *Raja* variety tubers increase in soluble dietary fiber fraction by 48% in comparison to fresh ones was observed (Table 1). According to Esposito et al. [10] it is caused by transformation of insoluble fiber fraction. In case of other variety, *Rosalind*, the reverse situation occurred – after cooking soluble fraction level was reduced by 12.6%, and in case of *Courage* variety no changes in this aspect were observed.

The next important health-promoting compound in potatoes is vitamin C. Potatoes are recognized as important sources of vitamin C in a human diet [4]. Vitamin C in potato tubers is present mostly in form of L- ascorbic acid, which contributes up to 92% of total amount of this vitamin [20]. As a result of applied thermal processing (Figure 1) it was noted a decrease of vitamin C content in tubers of all investigated varieties by 8 – 13%, the smallest changes were observed in case of *Rosalind*, the greatest in *Courage*. Obtained results found confirmation in works of other authors [27]. They reported losses in vitamin C content about 12 – 27%, and according to Burgos et al. [7] its level after cooking was reduced by 3 - 43%. Reduction of this compound in plant material after thermal treatment is caused by its extremely low thermal stability and good water solubility [7, 27].

Polyphenols are another health-promoting component in potato tuber with antioxidative properties, beside vitamin C, and their beneficial effect on human's organism is well documented [6, 9]. Total phenolic content (TPC) after cooking was reduced by 39% in *Raja* variety tubers, and by 46% in *Rosalind* and *Courage*, when compared to raw material (Table 2). Changes in polyphenols content after processing (often negative), including culinary processing, could be explained by co-operation of many factors i.e. washing out of phenolic compounds, thermal degradation, enzymatic oxidation and isomerization [32]. Opposite opinion was formed by Sahlin et al. [28], who demonstrated, that cooking of vegetables had small effect on polyphenols content when compared to drying process. All above mentioned changes in polyphenols content influenced vegetables antioxidative potential.

Similar situation occurred in case of flavonoids, because their content in cooked potatoes also was reduced. The smallest losses in flavonoids content were noted in case of *Raja* variety (6,1%), and the highest in *Courage* (46,5%) (Table 2). Losses in phenolic compounds content in sweet potatoes after cooking were observed by Jung et al. [18]. Turkmen et al. [33] observed reduction in polyphenols level in range 6 – 40% in vegetables after cooking. Also Dao and Fiedman [8] noted reduction by 65% of total phenolic content (TPC) in potatoes after cooking.

The noticeable effect of cooking was lowering of antioxidant activity of potatoes varieties *Raja* and *Rosalind*, respectively by 6% and 23% (measured by ABTS radical method), and by 7,5% and 10% by FRAP method, when compared to raw material. Reduction of antioxidant activity of potatoes varieties *Raja* and *Rosalind* after cooking was a logical consequence of polyphenols loss including flavonoids when compared to fresh ones (Table 2).

On the other hand thermal treatment of *Courage* variety tubers did not cause changes in their antioxidative capacity as compared to raw tubers, though reduced amounts of polyphenols, including flavonoids (Table 2) were measured. Such stabilization of antioxidative capacity in case of this variety could be explained by a fact, that other compounds which were not analyzed in this research (like tannins or other non-phenolic compounds) could also be liberated or created during thermal treatment. As an example Maillard reaction products could be proposed [21, 24].

Tabela 2. Aktywność antyoksydacyjna oraz zawartość polifenoli i flawonoidów w ziemniakach przed i po gotowaniu

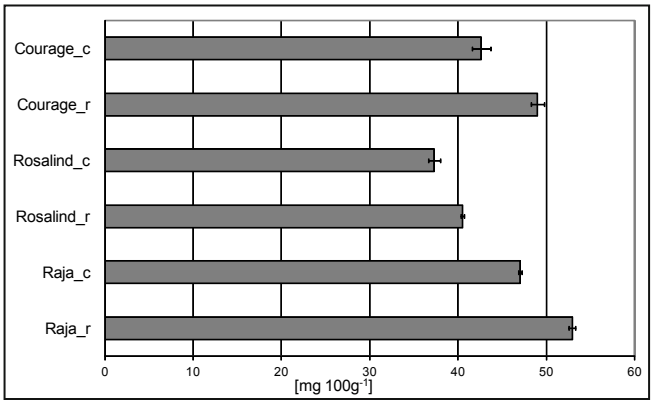
Table 2. Antioxidant activity and contents of polyphenolic compounds and flavonoids in potatoes before and after cooking

Sample	TEAC [mMTx·kg^{-1} d.m.]	FRAP [mMFe^{2+}·kg $^{-1}$ d.m.]	Total phenolic content (TPC) [mg catechin·g^{-1}d.m.]	Contents of flavonoids [mg rutin·g^{-1} d.m.]
RA_r	21.4±0.06^{d}*	13.30±0.18^{e}	3.09±0.19^{d}	0.82±0.01^{d}
RA_c	20.16±0.14^{c}	12.31±0.37^{d}	1.89±0.04^{c}	0.77±0^{c}
RO_r	18.37±0.30^{b}	6.28±0.21^{b}	2.12±0.22^{c}	0.73±0.04^{c}
RO_c	14.10±0.27^{a}	5.60±0.11^{a}	1.14±0.10^{a}	0.46±0.12^{ab}
C_r	25.47±0.32^{e}	11.30±0.13^{c}	2.96±0.28^{d}	0.71±0.03^{c}
C_c	25.24±0^{e}	11.26±0.16^{c}	1.59±0.09^{b}	0.38±0.07^{a}

*different letters in column denote mean values that statistically differ one from another (Duncan's test, at p=0.05)

Źródło: Badania własne

Source: The own study



Rys. 1. Zawartość witaminy C w bulwach ziemniaka przed i po ugotowaniu (średnia±SD).

Fig. 1. Vitamin C content in potato tubers before and after cooking (mean±SD).

Źródło: Badania własne

Source: The own study

Ismail et al. [14] stated, that vegetables boiled for 1 minute had antioxidative potential quite similar to the fresh ones, and in research conducted by Turkmen et al. [33] 16% decrease in antioxidative capacity of pea after cooking was observed.

Summarizing, content of basic nutritional components after thermal treatment (cooking) was changed, and content of polyphenols, vitamin C and dietary fiber was lowered. As a result antioxidative potential was diminished, that greatly affected functional properties of these vegetables.

CONCLUSION

1. Cooking negatively influenced the content of analyzed nutritional compounds, because of their partial degradation and washing.
2. Level of total and insoluble dietary fiber was lowered in all investigated varieties after cooking, the most visible reduction was observed in tubers of *Rosalind* variety.
3. Cooking process caused losses in vitamin C content, the greatest in case of *Courage* variety, the smallest in *Rosalind*.
4. Loss in polyphenols content, after thermal treatment (cooking), was observed in tubers of *Raja* and *Rosalind* varieties. It negatively influenced their antioxidant activity. Some exception was observed in case of *Courage* tubers variety, where antioxidant activity was not altered by cooking process, in spite of lowered level of total polyphenols, including flavonoids.
5. It was observed a detrimental effect of cooking on functional component content, like polyphenols, flavonoids, vitamin C and dietary fiber in potatoes.

WNIOSKI

1. Gotowanie bulw ziemniaków doprowadziło do częściowego rozkładu oraz wymywania analizowanych składników odżywczych, co wpłynęło negatywnie na ich zawartość.
2. Po ugotowaniu bulw ziemniaka we wszystkich analizowanych próbkach poziom błonnika całkowitego w tym frakcji nierozpuszczalnej był niższy, największa redukcja nastąpiła w bulwach odmiany *Rosalind*.
3. Proces gotowania powoduje straty zawartości witaminy C, największe zaobserwowano w przypadku bulw odmiany *Courage*, a najmniejsze w odmianie *Rosalind*.
4. Straty zawartości polifenoli na skutek gotowania obserwowano w odmianie *Raja* oraz *Rosalind*. Wpłynęło to negatywnie na aktywność antyoksydacyjną tych odmian. Wyjątkiem okazały się bulwy odmiany *Courage*, w których aktywność antyoksydacyjna nie ulegała zmianie na skutek gotowania, pomimo iż obniżeniu uległa zawartość polifenoli całkowitych, w tym flawonoidów.
5. Zaobserwowano szkodliwy wpływ gotowania na zawartość składników prozdrowotnych w ziemniakach, takich jak: polifenole, flawonoidy, witamina C oraz błonnik pokarmowy.

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