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ORIGINAL ARTICLE

ASSESSMENT OF THE NUTRITIONAL SAFETY OF NEW POTATOES IMPORTED TO POLAND USING AN ASCORBATE-NITRATE INDEX

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ABSTRACT

Background. New potatoes are imported to Poland mainly from the Mediterranean countries. In climate of the Mediterranean Basin potatoes can be grown twice a year. The different environment conditions during plant growth have effect on the tuber quality.

Objective. The aim of the study was to assess the nutrition safety of new potatoes imported to Poland in the winter period from Mediterranean countries on the basis of the ascorbate-nitrate index.

Material and methods. The study material included potatoes imported from Cyprus, Egypt and Israel, purchased in the Siedlce city, from the beginning of February to the end of March 2015. Laboratory tests were performed on a total of 54 potato samples. The contents of L-ascorbic acid was determined by titration method with the 2,6-dichlorophenolindophenol according to Tillmans and nitrate by spectrophotometric method based on the Griess reaction. The ascorbate-nitrate index (I_{AN}) as the ratio of L-ascorbic acid amount-to-nitrate amount in potato tubers was calculated.

Results. The L-ascorbic acid content in imported new potatoes ranged from 102.7 to 131.0 mg kg^{-1} and nitrate content from 22.70 to 64.74 mg $N\text{-}NO_3$ kg^{-1} of the fresh weight of tubers. The L-ascorbic acid content in potatoes imported from Cyprus was similar to potatoes of the same cultivar imported from Egypt. The L-ascorbic acid content in potatoes imported from Israel was at a similar or higher level than in potatoes originating from Cyprus or Egypt. The lowest nitrate were in potatoes imported from Egypt. The nitrate content determined in potatoes imported from Cyprus was almost 2.5-times higher than for potatoes of the same cultivar imported from Egypt, whereas the nitrate contents in potatoes imported from Israel was 1.6-2-times higher than in potatoes originating from Egypt. The I_{AN} was from 1.68 to 5.73. The I_{AN} for the potatoes imported from Egypt was above 2.5-times higher than for potatoes of the same cultivar imported from Cyprus, and almost 2-times higher than for potatoes imported from Israel.

Conclusion. The nitrate content in tested potato samples did not exceed the permissible content of 200 mg NO_3 kg^{-1} of the fresh weight of tubers. The I_{AN} value calculated for all tested potato samples was higher than 1, which indicates that new potatoes imported to Poland in the winter period from Mediterranean countries are safe for human health regarding the nitrate content.

Key words: *food safety, new potatoes, L-ascorbic acid, nitrate, ascorbate-nitrate index*

STRESZCZENIE

Wprowadzenie. Młode ziemniaki są importowane do Polski głównie z krajów śródziemnomorskich. W klimacie basenu Morza Śródziemnego ziemniaki można uprawiać dwa razy w roku. Różne warunki środowiska w okresie wzrostu roślin mają wpływ na jakość bulw.

Cel badań. Celem badań była ocena bezpieczeństwa żywieniowego młodych ziemniaków importowanych do Polski w okresie zimowym z krajów śródziemnomorskich na podstawie indeksu askorbinowo-azotanowego.

Materiał i metody. Materiał do badań stanowiły ziemniaki importowane z Cypru, Egiptu i Izraela, zakupione w Siedlcach w okresie od początku lutego do końca marca 2015 roku. Badania laboratoryjne wykonano na 54 próbkach ziemniaków. Oznaczono zawartość kwasu L-askorbinowego metodą miareczkowania za pomocą 2,6-dichlorofenolindofenolu według Tillmansa i azotanów (V) metodą spektrofotometryczną w oparciu o reakcję Griessa. Indeks askorbinowo-azotanowy (I_{AN}) wyliczono jako stosunek ilości kwasu L-askorbinowego do ilości azotanów (V).

Wyniki. Zawartość kwasu L-askorbinowego w młodych ziemniakach z importu wahała się od 102,7 do 131,0 mg kg^{-1}, a zawartość azotanów (V) od 22,70 do 64,74 mg N-NO3 kg^{-1} świeżej masy bulw. Zawartość kwasu L-askorbinowego w ziemniakach importowanych z Cypru była podobna jak w ziemniakach tej samej odmiany importowanych z Egiptu. Zawartość kwasu L-askorbinowego w ziemniakach importowanych z Izraela była podobna lub wyższa niż w ziemniakach pochodzących z Cypru lub Egiptu. Najmniej azotanów (V) zawierały ziemniaki importowane z Egiptu. Zawartość

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azotanów (V) w ziemniakach importowanych z Cypru była prawie 2,5 raza większa niż w ziemniakach tej samej odmiany importowanych z Egiptu, natomiast zawartość azotanów (V) w ziemniakach importowanych z Izraela była 1,6-2 razy większa niż w ziemniakach pochodzących z Egiptu. I_{AN} wynosił od 1,68 do 5,73. I_{AN} ziemniaków importowanych z Egiptu był ponad 2,5 raza wyższy niż ziemniaków tej samej odmiany importowanych z Cypru i prawie 2 razy wyższy niż ziemniaków importowanych z Izraela.

Wnioski. Zawartość azotanów (V) w badanych próbkach ziemniaków nie przekraczała dopuszczalnej zawartości 200 mg NO_3 kg^{-1} świeżej masy bulw. Wartość I_{AN} obliczona dla wszystkich badanych próbek ziemniaków była wyższa niż 1, co wskazuje, że młode ziemniaki importowane do Polski w okresie zimowym z krajów śródziemnomorskich są bezpieczne dla zdrowia człowieka pod względem zawartości azotanów (V).

Słowa kluczowe*: bezpieczeństwo żywności, młode ziemniaki, kwas L-askorbinowy, azotany (V), indeks askorbinowo-azotanowy*

INTRODUCTION

Potatoes provide significant amounts of beneficial bioactive components in the human diet, such as vitamin C, protein of high biological value, phenolic compounds, mineral compounds and others [3, 7, 9]. New potatoes contain higher amounts of some phytonutrients than mature potato tubers. In addition to, new potatoes are typically cooked and eaten with their skin on, thereby avoiding nutrient losses due to peeling and reducing leaching [20, 28]. Apart from nutrients, potatoes also contain bioactive non-nutrient components such as nitrates or glycoalkaloids [3, 9].

Potatoes are an important source of vitamin C (mainly L-ascorbic acid and smaller amounts of dehydroascorbic acid), contributing about 20% of the dietary intake in Europe. Ascorbic acid plays an important physiological function in the human body, assisting in the prevention of some diseases and the maintenance of good health [22]. A typical meal with 150-200 g boiled or baked potatoes (at least three medium-sized tubers) can provide about 45-50% of the recommended daily intake (RDI) of vitamin C [9].

Potatoes are not classified as a high nitrate-containing vegetable [34], however because of the large amounts consumed, they can make a significant contribution to the daily intake of nitrate in the human diet [3]. According to *Matin* et al. [23], up to 27% of the daily nitrate with food can be derived from potatoes. Nitrates are non-toxic, but their metabolites (nitrites, nitrosamine) can produce a number of health effects [5, 12, 34]. The accumulation of nitrates in potato tubers depends on environmental conditions, agricultural practices, cultivar as well as physiological maturity of the tubers [32, 37, 40]. Immaturity in potato tubers has been connected with high nitrate levels, but the relationship between nitrate concentration and maturity is not clear and differs between genotypes [13].

Early potato is a typical crop grown in most of the Mediterranean countries. New potatoes are one of the most important crops exported from the Mediterranean area to the central and northern European markets. In climate of the Mediterranean Basin potatoes are mainly grown in off-season crops: winter-spring (planting from December to January and harvesting from March to early June) or summer-autumn (planting in early September and harvesting from November to the end of January). Cultivation is often carried out twice a year [13, 14]. The different climate conditions can have effect on the tuber quality. When tuber harvest time was delayed, the ascorbic acid content increased in winter-spring crops and decreased in summer-autumn crops, whereas the nitrate contents significantly decreased in the winter-spring crop and increased in the summer-autumn crop [13, 16].

There was a significant correlation found between the ascorbic acid content and nitrate level in potato tubers [4, 25]. The relative levels of these components may be expressed using the ascorbate-nitrate index (I_{AN}) [18]. The I_{AN} is one of the indicator of food safety. A higher index value reflects higher food safety. Thus, vegetables can be classified into three groups based on the ascorbate-nitrate index value according to the health risk; <0.5 indicates a risk, 0.5-1.0 is considered harmless while >1.0 is absolutely safe. The ascorbate-nitrate index was significantly influenced by the species of vegetable, the cultivar and the year of cultivation. Many vegetables have an ascorbate-nitrate index over 1.0 and can be regarded as nutritionally safe [30]. It has been shown that ascorbic acid may inhibit nitrosamine synthesis [26, 35]. In recent years, there has been an increase demand of new potatoes imported from Mediterranean area, which prompts a need to estimate their nutrition safety.

The aim of the study was to assess the nutrition safety of new potatoes imported to Poland in the winter period from Mediterranean countries on the basis of the ascorbate-nitrate index.

MATERIAL AND METHODS

The study material included imported new potatoes purchased in small local fruit and vegetable shops and in supermarkets once a week in the city of Siedlce (Poland) from the beginning of February to the end of March. Each time, three samples of each cultivar of potato, each weighing from 1 to 1.5 kg, were purchased. A total of 54 potato samples were purchased for the study. Four potato cultivars were analysed imported from three countries (Table 1).

Table 1. Characteristics of potato cultivar [6]

Cultivar	Country of origin	Potato imported from	Tuber shape	Tuber flesh colour	Cooking type*
Spunta	Netherland	Cyprus, Egypt	long to oval	light yellow	B
Nicola	German	Israel	oval to long	light yellow	A
Maris Peer	United Kingdom	Israel	oval	cream	A
Orchestra	Netherland	Israel	round-oval	light yellow	AB

*Cooking type: A – salad, AB – salad to general purpose, B – general purpose

The potatoes purchased in February were imported from Cyprus (n=15), and in March from Cyprus (n=15), Egypt (n=9) and Israel (n=15). Only potatoes imported from Cyprus exhibited the characteristics of early potatoes, consistent with United Nations Economic Commission for Europe Standard FFV-52 concerning the marketing and commercial quality control of early and ware potatoes, i.e. were harvested before they are completely mature, marketed immediately after their harvesting, and whose skin can be easily removed without peeling [38]. The other potatoes introduced to the market as new potatoes were harvested after completely mature, had corky skins and were washed and packed.

Potatoes were washed, blotted dry and homogenized. Ten grams samples of homogenized potatoes were used for laboratory analyses. The content of L-ascorbic acid was determined using the titration method with 2,6-dichlorophenolindophenol (DCPIP) according to Tillmans after extraction with 2% oxalic acid ($C_2H_2O_4 \cdot H_2O$) [31]. The content of nitrate was determined with the spectrophotometric method based on the Griess reaction after reduction of the nitrates to nitrites with cadmium dust. The absorbance was measured at a wavelength of 538 nm [17]. All laboratory analyses were in duplicate and the mean results were expressed in mg per 1 kg of the potatoes fresh weight. The ascorbate-nitrate index as the ratio of L-ascorbic acid amount-to-nitrate amount in potato tubers was calculated [18].

The results of the study were analysed statistically using *Student's* t-test. Statistical analysis was performed for three replication of each potato cultivar. The significance of differences was verified using *Tukey's* test at $p = 0.05$.

RESULTS AND DISCUSSION

The L-ascorbic acid content in tested new potatoes samples ranged from 102.7 to 131.0 mg kg^{-1} fresh weight (Table 2). Potatoes of the same cultivar, oryginating from the same country, differed in terms of the L-ascorbic acid content. The L-ascorbic acid content in 'Spunta' potatoes imported from Cyprus was similar to the potatoes of this cultivar originating from Egypt.

Table 2. L-ascorbic acid content in potato tuber (mg kg^{-1} of the fresh weight of tubers)

Potato imported from	Cultivar	No of samples	Range min – max	Mean*
Cyprus	Spunta	30	105.0-131.0	113.5 b
Egypt	Spunta	9	102.7-130.0	119.7 ab
Israel	Nicola	9	103.7-118.0	110.1 b
Israel	Maris Peer	3	117.0-118.0	117.7 ab
Israel	Orchestra	3	125.0-127.0	126.3 a

*Means followed by the same letters do not differ significantly at p=0.05

The L-ascorbic acid content in tubers of 'Nicola' and 'Maris Peer' was similar, and in tubers of 'Orchestra' was higher than in potatoes originating from Cyprus and 'Nicola' from Israel. The differences in the Lascorbic acid content in potatoes imported from Israel could be due to the biological characteristics of plants and date of import, and number of tested samples. 'Nicola' was imported in the first half of March and 'Maris Peer' and 'Orchestra' at the end of March. Early potato production in Mediterranean countries (e.g. Egypt, Cyprus, Israel, Morocco or in southern Italy) twice a year requires cultivars that can adapt to contrasting climate conditions. Cultivation is carried out in a winter-spring crop utilising seed-tubers of foreign cultivars (from northern European countries) and in summer-autumn crop seed-tubers produced locally [14]. 'Spunta' is the most common cultivar grown in the Mediterranean area in both the winter-spring and the summer-autumn seasons [1]. In the present study, the L-ascorbic acid content determined in 'Spunta' potatoes imported from Cyprus and Egypt was almost two times lower than that grown in southern Italy in a region with a typical maritime-Mediterranean climate [1]. Considering its good tuber quality characteristics, this cultivar is recommended in areas with a good water supply [15].

The L-ascorbic acid content in ‘Spunta’ potatoes grown in Cyprus and ‘Nicola’ grown in Israel did not differ significantly, which was confirmed by a study carried out in southern Italy [16]. The ascorbic acid content in early potato crops in Mediterranean countries depends on the growing season, cultivar and harvest date. When harvest time is delayed, ascorbic acid content increases in winter-spring and decreases during the summer-autumn growing season [16]. This opposite trend could be caused by a reduction of sunlight intensity and day-length during potato growth period. The higher the light intensity during the plant growth period, the higher is ascorbic acid content in plant tissues [19]. Because monosaccharides are necessary for the synthesis of ascorbate acid, the content of this compound is closely related to the intensity of photosynthesis. Ascorbic acid is translocated from the leaves to the potato tubers via phloem flow [36]. Other studies have associated increased levels of L-ascorbic acid in potatoes with higher temperatures, lower rainfall and sandy soil [10, 24] and higher L-ascorbic acid levels were found in potatoes grown in more basic soil [2]. In conditions of southern Italy, the ascorbic acid contents in tubers of ‘Spunta’ and ‘Nicola’ were very similar in the winter-spring and summer-autumn growing season [16]. In the present study, the L-ascorbic-acid content in ‘Nicola’ potatoes was lowest with all tested cultivars, whereas Valcarcel et al. [39] reported that the L-ascorbic acid content in mature tubers of this cultivar was the highest among the sixty tested cultivars of potato grown in Ireland.

The nitrate content in tested new potatoes samples ranged from 22.70 to 64.72 mg N-NO_3 kg^{-1} of the fresh weight of tubers (Table 3) and did not exceed the permissible content of 200 g NO_3^- kg^{-1} of the fresh weight of tubers [38]. The nitrate content in tested potatoes samples was more differ than the L-ascorbic acid content. Accumulation of nitrate in potato tubers depends on environmental conditions, agricultural practices, cultivar properties and tuber physiological maturity [11, 32, 40]. The lowest nitrate content was determined in potatoes imported from Egypt.

Table 3. Nitrate content in potato tuber (mg N-NO_3 kg^{-1} of the fresh weight of tubers)

Potato imported from	Cultivar	No of samples	Range min – max	Mean*
Cyprus	Spunta	30	49.69-64.72	56.99 a
Egypt	Spunta	9	22.70-24.04	23.18 d
Israel	Nicola	9	35.76-38.94	37.27 c
Israel	Maris Peer	3	47.54-48.02	47.77 b
Israel	Orchestra	3	45.44-46.02	45.65 b

*Means followed by the same letters do not differ significantly at p=0.05

The nitrate content determined in ‘Spunta’ potatoes imported from Cyprus was almost 2.5-times higher than for tubers of the same cultivar imported from Egypt. The nitrate content in potatoes imported from Israel was 1.6-2-times higher than in potatoes imported from Egypt. The nitrate content in potatoes of the ‘Maris Peer’ and ‘Orchestra’ imported from Israel was at a similar level, and was higher, on average, by about 10 mg N-NO_3 kg^{-1} of the fresh weight of tubers compared to ‘Nicola’ imported from the same country. In a study carried out by other authors, the nitrate content in ‘Nicola’ potatoes in winter-spring crop in southern Italy amounted 670 mg NO_3 kg^{-1} of the dry matter of tubers in conventional cultivation system and 440 mg NO_3 kg^{-1} of the dry matter of tubers in an organic cultivation system [21]. Nitrates are accumulated in potato tubers when their uptake is greater than the possibility of the plant to its utilise in organic nitrogenous compounds. The level of nitrate determined in ‘Spunta’ potatoes imported from Cyprus was at a similar level than for tubers of the same cultivar cultivated in Sicily [13]. In early potato production in the Mediterranean region, the nitrate content in tuber depends on the growing season. In general, a higher tuber nitrate content in winter-spring than in summer-autumn crop was found. This may be explained with sunlight intensity and day-length. Low intensity of sunlight cause an increase in the accumulation of nitrates due to the lower activity of nitrate reductase. By delaying potatoes harvest, nitrate contents significantly decreased in the winter-spring crop and increased in the summer-autumn crop, when the day is getting longer and shorter, respectively [13, 14]. In general, immaturity in potato tubers has been connected with high nitrate levels. The later the potatoes are harvested, the lower the nitrate contents are in tubers, but the relationship between nitrate content and tuber maturity differs between genotypes [11, 32]. In a study carried out in southern Italy, the nitrate content in ‘Spunta’ potatoes amounted to 173 mg NO_3 kg^{-1} of the fresh weight of tubers at 90 days after planting in the winter-spring crop and 42 mg NO_3 kg^{-1} of the fresh weight of tubers at 80 days after planting in the summer-autumn crop. Delaying potatoes harvest by 25-30 days caused decrease in the nitrate content by 64% in the winter-spring crop and increased in the nitrate content by about 72% in the summer-autumn crop [14]. The Acceptable Daily Intake (ADI) of nitrates has been established as being 0-3.7 mg kg^{-1} body weight per day by the European Commission's Scientific Committee on Food (CSF) [29] and the Joint Expert Committee of the Food and Agriculture (JECFA) organisation belonging to the United Nations/World Health Organization (FAO/WHO) [8]. Assuming that the daily consumption of potatoes is approximately 200 g (at last three medium-sized tubers), the nitrate intake with new potatoes ranged from 4.54 to 12.94 mg $N\text{-}NO_3$, and did not exceed ADI for an adult person weighing 60 kg. On the other hand, the nitrate content in potatoes are significantly reduced during the culinary processes [27].

The ratio of L-ascorbic acid amount-to-nitrate amount in the tested new potatoes samples ranged from 1.68 to 5.73 (Table 4). In a study carried out by *Mazurczyk* and *Lis* [25], the ratio of Lascorbic acid amount-to-nitrate amount for mature tubers of several of the twenty one tested potato cultivars ranged from 4.4 to 12.4. The higher content of vitamin C per unit was accompanied with the lower nitrate content by about five units. In the present study, the highest ascorbate nitrate index (I_{AN}) value was obtained for the 'Spunta' potatoes imported from Egypt. The average I_{AN} calculated for the 'Spunta' potatoes imported from Egypt was above 2.5 times higher than for tubers of the same cultivar imported from Cyprus. The I_{AN} calculated for potatoes of the 'Nicola', 'Maris Peer' and 'Orchestra' imported from Israel was at the similar level, and was higher than for potatoes imported from Cyprus. The I_{AN} value calculated for all tested potato samples was higher than 1, which indicates that the new potatoes imported to Poland in the winter period from Mediterranean countries were safe for human health regarding the nitrate content. A higher I_{AN} value reflects a more potent action of ascorbic acid and less harmful nitrates in the plant [30, 33].

Table 4. Ascorbate-nitrate index for potato tuber

Potato imported from	Cultivar	No of samples	Range min – max	Mean*
Cyprus	Spunta	30	1.68-2.58	2.01 c
Egypt	Spunta	9	4.27-5.73	5.18 a
Israel	Nicola	9	2.90-3.03	2.95 b
Israel	Maris Peer	3	2.47-2.49	2.48 bc
Israel	Orchestra	3	2.75-2.79	2.77 b

*Means followed by the same letters do not differ significantly at $p=0.05$

CONCLUSIONS

1. The L-ascorbic acid content in new potatoes imported from Cyprus was similar to potatoes of the same cultivar imported from Egypt. The L-ascorbic acid content in potatoes imported from Israel was at a similar or higher level than in potatoes originating from Cyprus or Egypt.
2. The lowest nitrate levels were in new potatoes imported from Egypt. The nitrate content determined in potatoes imported from Cyprus was almost 2.5-times higher than for potatoes of the same cultivar imported from Egypt, whereas the nitrate contents in potatoes imported from Israel was 1.6-2-times higher than in potatoes originating from Egypt.
3. The highest I_{AN} value obtained for the potatoes imported from Egypt was above 2.5-times higher than for potatoes of the same cultivar imported from Cyprus, and almost 2-times higher than for potatoes imported from Israel.
4. The nitrate content in tested potato samples did not exceed the permissible content of 200 mg NO_3 kg^{-1} of the fresh weight of tubers. The I_{AN} value calculated for all tested potato samples was higher than 1, which indicates that new potatoes imported to Poland in the winter period from Mediterranean countries are safe for human health regarding the nitrate content.

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Conflict of interest
The authors declare no conflict of interest.

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