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Changes in glycoalkaloids content of potatoes destined for consumption

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Abstract

The purpose of the present study was to determine glycoalkaloid content of early potato cultivars, grown with the use of various *N* rates and subsequent changes resulting from preparation of potatoes for consumption. The material taken for the study consisted of three very early potato cultivars from the growing seasons of 2003–2005: Bard, Lord and Denar, grown in the experimental plots belonging to Wroclaw University of Environmental and Life Sciences.

Very early potato cultivars (Bard, Lord and Denar) exhibited low glycoalkaloid content (<2 mg/100 g), while the ratios of α-solanine to α-chaconine were from 1:1.9 to 1:2.5. Glycoalkaloids content of potato tubers, depended on potato cultivar and *N* rates used during cultivation. A double *N* rate, increased glycoalkaloids content by 10%. After peeling and cooking, the glycoalkaloid content of potatoes decreased from 75% to 80%, depending on potato cultivar. The losses of glycoalkaloids were twice higher after peeling than after cooking. The losses of solanine were higher than those of chaconine, both after peeling and cooking of the potatoes. The ratio of solanine to chaconine in cooked potatoes was 1:4 and 1:2 before peeling.

Keywords: Glycoalkaloids (α-Solanine; α-Chaconine); HPLC; Potatoes for consumption; N-fertilization

1. Introduction

Potato tubers contain both valuable nutrients and natural toxic substances, such as glycoalkaloids. Generally, glycoalkaloid content is referred to as TGA (total glycoalkaloids) (Lisińska & Leszczyński, 1989). Glycoalkaloids content of mature potato tubers is found within the range from 3 to 10 mg/100 g of the potato (Friedman, 2004; Lisińska & Leszczyński, 1989; Pęksa, Gołubowska, Rytel, Lisińska, & Aniołowski, 2002; Speijers, 1998). Increased levels of these compounds (14–15 mg/100 g) result in bitter flavour of the potatoes (Osman, 1983), while 20 mg/100 g is considered hazardous to human health (Korpan et al., 2004; Rodriguez-Saona, Wrolstad, & Pereira, 1999).

Glycoalkaloids present in potato tubers, contain α-solanine (about 40%) and α-chaconine (about 60%) (Friedman, 2004; Maga, 1980; Stanker, Kamps-Holtzapple, & Friedman, 1994). The concentration ratios of α-solanine to α-chaconine vary, depending on the anatomy or cultivar of potato plant and can be found within the ranges from 1:2 to 1:7 (Bejarano, Mignolet, Devaux, Carrasco, & Larondelle, 2000; Speijers, 1998).

Glycoalkaloid accummulation in potato tubers is a complex process and their total amount depends on various factors, such as potato cultivar, soil and weather conditions during growing season, fertilizer use, potato maturity at harvest time, tuber sizes, mechanical damage, storage conditions and access to light (Brandt & Mølgaard, 2001; Frydecka-Mazurczyk & Zgórska, 2002; Haddadin, Humeid, Qaroot, & Robinson, 2001; Machado, Toledo, & Garcia, 2007; Percival, 1999; Şengül, Keleş, & Keleş, 2004; Tajner-Czopek, Leszczyński, Lisińska, & Prośba-Białczyk, 2006).

Glycoalkaloid accumulation in potato tubers is to a large extent dependent on the cultivar, therefore, it is

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important to eliminate those which are able to synthesize large amounts of these compounds during the growing season or during storage (Pęksa et al., 2002; Sinden, Stanford, & Webb, 1984).

Another factor affecting glycoalkaloids concentration is overdosage of mineral fertilization, especially too high *N* rates (Leszczyński, 2002; Love, Herrman, Thompson-Johns, & Baker, 1994; Rogozińska, 1995).

Glycoalkaloids content of potato tubers is decreasing during growing and upon maturation (Lisińska & Leszczyński, 1989; Pęksa et al., 2002). The content of these compounds can be 1.5 times as low in physiologically mature potatoes as compared to that of immature tubers (Tajner-Czopek et al., 2006).

A major portion of glycoalkaloids is present in the skin or immediately beneath it; particularly high concentrations are found around potato eyes (Lisińska & Leszczyński, 1989; Pęksa et al., 2002; Wünsch & Munzert, 1994). Preliminary processing, e.g., peeling and cooking can reduce these compounds in the raw material (Rytel, Gołubowska, Lisińska, Pęksa, & Aniołowski, 2005). When the peels are removed, glycoalkaloid content can be reduced by 50–95% (Frydecka-Mazurczyk & Zgórska, 1997), while glycoalkaloids extraction to the cooking liquor is negligible. On the other hand, frying, baking or microwave cooking, markedly reduce glykoalkaloids content of snacks or dried potato products (Friedman & McDonald, 1997; Friedman, 2004; Pęksa et al., 2002; Pęksa, Gołubowska, Rytel, Lisińska, & Aniołowski, 2006).

Due to the toxic effects of glycoalkaloid compounds present in potatoes, comprehensive studies on changes in their content, resulting from growing and processing technologies, are required.

The purpose of the present study was to determine glycoalkaloids content of early potato cultivars grown with the use of various *N* rates and subsequent changes resulting from preparation of potatoes for consumption.

2. Materials and methods

2.1. Raw material

The material taken for the study consisted of three very early potato cultivars from the growing seasons of 2003–2005: Bard, Lord and Denar, grown in the experimental plots belonging to Wroclaw University of Environmental and Life Sciences. The experiment was carried out in three replications, with the use of N fertilizer at the following rates: 40, 80, and 120 kg N ha^{-1}.

2.2. Methods of sample collection

The samples of potato tubers (20 kg each) were harvested after reaching full maturity (after 100 days of the growing season). The potatoes from the plot fertilized with a rate of 40 kg N ha^{-1} were peeled and cooked.

2.3. Potato samples preparation for the analysis

Raw, peeled and cooked tubers were cut in 1 cm thick slices and freeze-dried. The dry material obtained, after being ground in electric grinder, became the material used for defining the contents of α-solanine and α-chaconine.

2.4. Apparatus

A high-pressure liquid chromatograph HPLC (ProStar) were used, made by the Varian company (Walnut Creek, CA, USA), equipped with UV detector – 310 type, analytical column Mikrosorb NH_2 (25 × 0.46 cm L.D.) (Rainin Instrument, Woburn, MA, USA) and a computer system monitoring the chromatograph (Varian Chromatography System) (Pęksa et al., 2002).

2.5. Conditions of the glycoalkaloids separation

As an eluent, a mixture of tetrohydrafuran, acetonitrile and redistilled water 50:20:30 + KH_2PO_4 (1.02 g/dm^3 mixture) was used. The process was carried out at a temperature of 35 °C, with the speed of flow of 2 cm^3/min and the pressure of 113 atm, applying the light wavelength of 208 nm (Pęksa et al., 2002).

2.6. Sample preparation for the chromatographic analysis

The freeze-dried material (1 g) was homogenized with 4 cm^3 redistilled water and 30 cm^3 of methanol for 2 min followed by filtration. The filtrate was brought to a final volume of 50 cm^3 with methanol. A 5 cm^3 aliquot of the extract was cleaned up on the SPE column (Bond Elut C18; 500 mg; 6.0 cm^3 ml) (Varian, USA). Glycoalkaloids were rinsed with methanol and evaporated to dryness in vacuum at a temperature of 50 °C. The residue formed was dissolved in 1 cm^3 of THF:ACN:H_2O – 50:20:30. Before application onto the column, the sample was cleaned up by using filters of 0.45 μm. The volume of the injection was 10 μm.

Standard solutions (1 mg/cm^3) were prepared by dissolving 10 mg of α-solanine and α-chaconine (Sigma) in 10 cm^3 of methanol; 10 μl, containing from 1 to 50 μg/cm^3 both α-solanine and α-chaconine, were injected (Pęksa et al., 2002).

2.7. Analytical methods

The dry matter of fresh potato samples and freeze-dried material was determined by the reduced weight after drying at 102 °C and until constant weight was achieved (AOAC, 1995). The quantities of α-solanine and α-chaconine were determined by the method of Pęksa et al. (2002) and Saito et al. (1990). All analyses were carried out in duplicate.

2.8. Statistical analysis

The results obtained in the experiment were subjected to statistical calculations according to Statistica 7.1 program.

Two-way analysis of variance was used for determining the significance of the influence of potato variety and the fertilization doses on the contents of total glycoalkaloids, α-solanine and α-chaconine in potato tubers, and one-way analysis of variance was used for determining, the significance of the influence of stage of culinary process on the contents of total glycoalkaloids, α-solanine and α-chaconine in studied samples.

3. Results and discussion

3.1. Cultivars

Gycoalkaloid content of very early potato cultivars taken for the study was low. On average, Denar contained 1.72 mg/100 g of total glycoalkaloids (TGA), while glycoalkaloids content of two remaining cultivars was about 10% higher (Table 1). TGA of potato tubers used for the studies by other authors was higher: Bejarano et al. (2000) reported the ranges from 5.2 to 12.2 mg/100 g; Friedman, Roitman, and Kozukue (2003) from 0.7 to 18.7 mg/100 g, and Pęksa et al. (2002) found the ranges from 6.3 to 13.7 mg/100 g. In general, early potato cultivars are higher in glycoalkaloids than late varieties. It is worth noting that new Polish cultivars: Bard, Lord and Denar, despite being very early, exhibit low susceptibility to the formation of toxic substances, among them glycoalkaloids.

The results obtained in the present study show that the ratio of solanine to chaconine found in Bard and Lord cultivars was 1:2, while that of Denar was slightly higher and amounted to 1:2.5 (Table 2). The ratios found between the two toxic substances are in concurrence with other data reported in literature. Dale, Griffiths, and Brain (1998), Friedman et al. (2003) and Wünsch and Munzert (1994) report that the ratio of solanine to chaconine is cultivar dependent and can be found within the ranges from 1:2 to 1:7. Pęksa et al. (2002) studied Aster, Mila and Bryza potato cultivars and found the ratios of α-solanine to α-chaconine within the ranges from 1:2.4 to 1:4. Friedman et al. (2003) who studied May Queen potato cultivar, found a ratio of solanine to chaconine at 1:2.4. Tajner-Czopek et al. (2006) report that the ratio of solanine to chaconine in mature potato tubers is higher (1:2.7) as compared to that found in potatoes harvested on earlier dates, which showed a ratio of 1:2.3.

Table 2

The ratio of α-solanine to α-chaconine concentration of unpeeled, peeled and cooked potato tubers of three potato varieties (mean values for the years 2003–2005)

Potato variety	Unpeeled	Peeled	Cooked
Bard	1:1.9	1:3.3	1:3.3
Lord	1:2.0	1:3.4	1:4.0
Denar	1:2.5	1:2.4	1:3.9

3.2. Fertilization

Increased *N* rates used in potato cultivation enhanced the glycoalkaloid content of potato tubers. Glycoalkaloid content of potatoes from the plots fertilized with 40 kg of N ha^{-1} amounted to 1.74 mg/100 g, which was markedly lower than that of potatoes fertilized with a double rate, i.e., 1.94 mg /100 g (Table 1). When *N* rate was increased

Table 1

The content of total glycoalkaloids (mg/100 g raw material) of potato tubers of three potato varieties fertilized with different *N* rates (mean values for the years 2003–2005)

Rates of nitrogen fertilization (kg N ha^{-1})	Variety				
	Bard	Lord	Denar	Mean doses	LSD
	Total glycoalkaloids				
40	1.84	1.79	1.58	1.74 ± 0.03^{a}	0.09
80	1.98	1.89	1.76	1.88 ± 0.06^{b}	
120	1.82	2.19	1.83	1.94 ± 0.05^{b}	
Mean varieties	1.88 ± 0.04^{b}	1.96 ± 0.05^{b}	1.72 ± 0.03^{a}		
LSD	0.09				
	α-Chaconine				
40	1.23	1.19	1.13	1.18 ± 0.04^{a}	0.06
80	1.27	1.27	1.30	1.27 ± 0.05^{b}	
120	1.20	1.43	1.25	1.29 ± 0.05^{b}	
Mean varieties	1.23 ± 0.04^{a}	1.29 ± 0.05^{b}	1.23 ± 0.03^{a}		
LSD	0.06				
	α-Solanine				
40	0.61	0.60	0.45	0.55 ± 0.02^{a}	0.04
80	0.71	0.62	0.46	0.60 ± 0.03^{b}	
120	0.62	0.76	0.58	0.65 ± 0.02^{c}	
Mean varieties	0.65 ± 0.02^{b}	0.66 ± 0.03^{b}	0.49 ± 0.03^{a}		
LSD	0.04				

LSD, least significant difference ($^{*}p < 0.05$) a, b, c – column/line values with the same letter are not significantly different.

[a–c] – values are given as mean ± SD = 18.

from 40 to 120 kg N ha^{-1} chaconine content increased by 9%, and solanine by 18%. Love et al. (1994) report that with the increasing *N* rates from 0 to 340 kg ha^{-1}, glycoalkaloids content was found within the ranges from 3.7 to 4.6 mg/100 g. The results obtained by Rogozińska (1995) show that *N* rates of: 0, 50, 100, 150, 200 kg N ha^{-1} affected glycoalkaloids content, which was found within the range from 1.44 to 3.96 mg/100 g.

3.3. Peeling and cooking

Preparation of potato tubers for consumption (peeling and cooking) markedly reduced the glycoalkaloid content of potatoes and the decrease was more pronounced after peeling than after cooking (Fig. 1). On average, peeling resulted in a 58% decrease in total glycoalkaloids content (Fig. 1), 54% decrease in chaconine (Fig. 2) and about 67% decrease in solanine (Fig. 3). Greater losses of glycoalkaloids were found with Bard variety as compared with Denar and Lord. The place of glycoalkaloids in potato tubers is not uniform – larger amounts are present in the skin and beneath it Pęksa et al. (2002) and Smith et al. (1996), and for this reason, peeled potatoes contain only half the toxic substances. According to Cieślik (1998), the losses of glycoalkaloids in peeled potatoes can account for 51–74%, depending on potato cultivar, tuber size and peeling technologies. Pęksa et al. (2006) found the losses even higher, from 72% to 78%.

Peeling also affected the percentages of α-solanine and α-chaconine in total glycoalkaloids content, but this effect was not observed in all the potato cultivars under investigation (Table 2). The ratio of solanine to chaconine in Bard and Lord varieties increased after peeling from 1:2.0 to 1:3.4. However, no similar changes were found with Denar variety. Rytel et al. (2005) report that peeled potatoes are

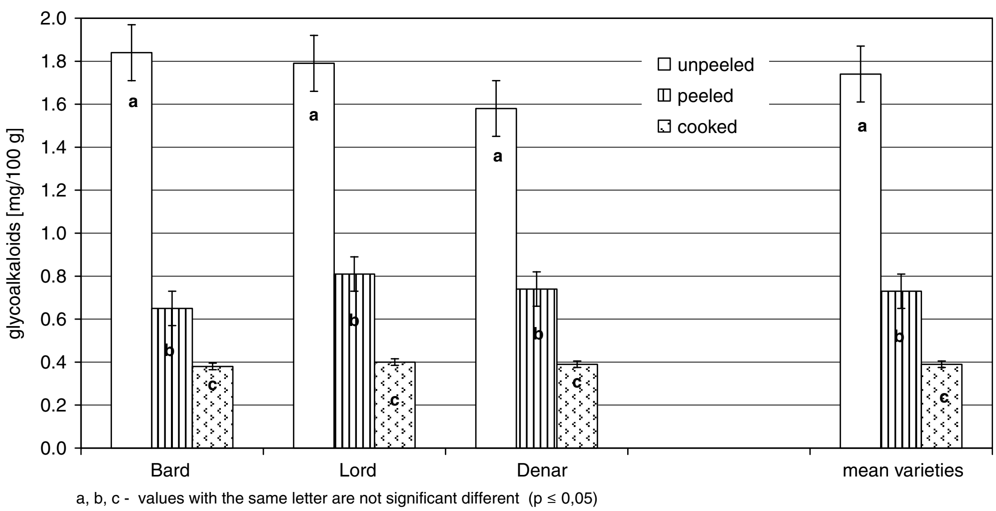

Fig. 1. Changes in the sum of glycoalkaloids content of three potato varieties (unpeeled, peeled and cooked).

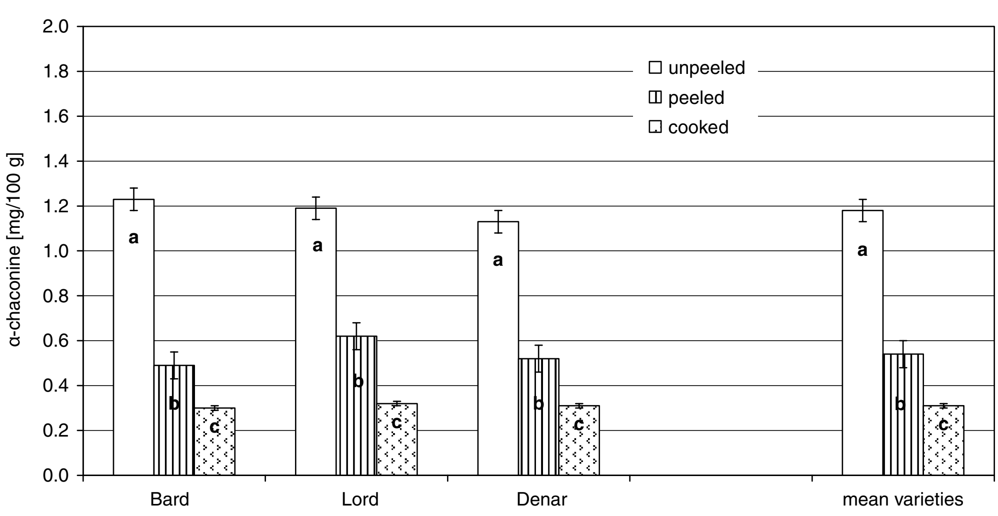

Fig. 2. Changes in the α-chaconine content of three potato varieties (unpeeled, peeled and cooked).

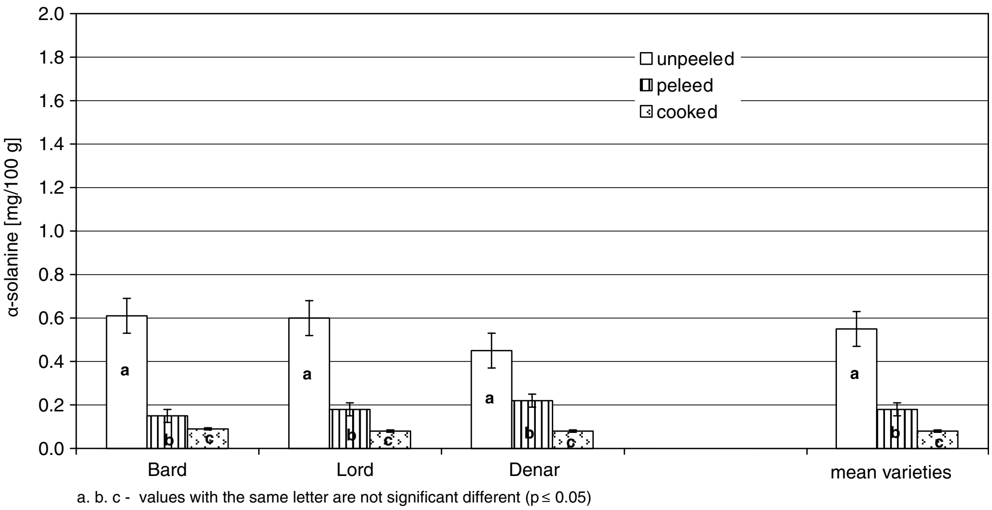

Fig. 3. Changes in the α-solanine content of three potato varieties (unpeeled, peeled and cooked).

much lower in glycoalkaloids, but a decrease in solanine is significantly higher than that of chaconine.

Further reductions in glycoalkaloids content were observed in cooked potatoes, but to a lower extent than after peeling. The losses due to cooking averaged 22% of total glycoalkaloids (Fig. 1), about 23% of chaconine (Fig. 2) and about 18% of solanine (Fig. 3). Both cooking and peeling resulted in greater losses of solanine than chaconine. The solanine to chaconine ratios in cooked potatoes were from 1:3.3 – (Bard variety) to 1:4.0 – (Lord variety) (Table 2). The losses of glycoalkaloids resulting from peeling are twice as high as those resulting from cooking. Cieślik (1998) concludes that this phenomenon is due to thermal stability of glycoalkaloids. According to the same author, the losses of glycoalkaloids due to cooking also depends on a cooking method; traditional in water or in a microwave.

4. Conclusions

Very early potato cultivars (Bard, Lord and Denar) exhibited low glycoalkaloid content (<2 mg/100 g), while the ratios of α-solanine to α-chaconine were from 1:1.9 to 1:2.5. Glycoalkaloid content of potato tubers depended on the potato cultivar and *N* rates used during cultivation. A double *N* rate increased glycoalkaloids content by 10%. After peeling and cooking, the glycoalkaloid content of potatoes decreased from 75% to 80%, depending on potato cultivar. The losses of glycoalkaloids were twice as high after peeling than after cooking. The losses of solanine were higher than those of chaconine, both after peeling and cooking of the potatoes. The ratio of solanine to chaconine in cooked potatoes was 1:4 and 1:2 before peeling. The new Polish cultivars exhibited low glycoalkaloids content, even with increased *N* rates, which is important with regard to food safety and human health. The primary glycoalkaloid content of potatoes was reduced by peeling and cooking.

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