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Food Chemistry 97 (2006) 151–156
Food Chemistry
www.elsevier.com/locate/foodchem

# Changes of glycoalkaloids and nitrate contents in potatoes during chip processing

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Received 23 March 2005; accepted 23 March 2005

**Abstract**

Changes in the glycoalkaloids, α-solanine and α-chaconine, and nitrate contents in potatoes of two varieties, *Karlena* – middle-early and *Saturna* – middle-late, were investigated during chip processing. The material for the study comprised samples from six stages of a chip production line. In the freeze-dried samples of potato and defatted chips obtained, the contents of α-solanine and α-chaconine were determined by HPLC and nitrates ($NO_3^-$) by reflectometer apparatus RQflex. Significant decrease of glycoalkaloids, particularly α-solanine, and nitrates contents during the process of chips production was observed. The ratio of α-chaconine to α-solanine contents during potato processing was maintained at a similar level during the whole process and was about 2.5:1. The highest amounts of glycoalkaloids were removed during peeling, slicing, washing and frying, and the highest amounts of nitrates during peeling and frying.


*Keywords:* Glycoalkaloids; Nitrates; Potato; Stages of chip processing

## 1. Introduction

Due to nutritive value of potatoes, the possibility of cultivating potatoes in many regions of the world, nutritional habits in many countries, as well as the wide range of products which can be obtained from potatoes, there is significant interest in potato products all over the world. However, the form of potato consumption is changing – consumers more and more often reach out for industrially processed potato products.

Semi products, as well as ready to eat potato products, contain the same nutritive components as potato itself, but in different amounts depending on the product. During chips processing some component found in the upper layers of potato tubers removed during peeling. During the next processing stages, the contents of soluble substances in potatoes decrease to the advantage of insoluble components (Mondy & Gosselin, 1988; Smith, Roddick, & Jones, 1996). Apart from nutritive components in potatoes, during processing the contents of toxic substances, such as glycoalkaloids (α-solanine and α-chaconine) and nitrates (V and III) change. Potatoes available in the market or assigned to the food industry usually contain significantly less glycoalkaloids and nitrates than accepted limits. Contents of glycoalkaloids in potato tubers of most edible varieties oscillate between 3 and 10 mg/100 g of fresh matter (Leszczyński, 1994, 2000; Speijers, 1998; Wünsch & Munzert, 1994), while contents of nitrates oscillate between 4 and 50 mg/100 g (Leszczyński, 1994, 2000; Lisińska & Leszczyński, 1989). The limit of glycoalkaloid contents of 20 mg/100 g, accepted at the beginning of the 20th century, is rarely exceeded (Leszczyński, 1994; Papathanasiou, Mitchell, & Harvey, 1998; Sinden, Sanford,

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doi:10.1016/j.foodchem.2005.03.035

& Webb, 1984; Smith et al., 1996). It is assumed that edible potato should not contain more than 250 mg of $KNO_3$/kg of wet basis (Cieślik, Międzybrodzka, & Sikora, 1990), while the allowable dose of nitrates, which is 0.2 mg/kg of human body mass, confirms that consumption of potato, particularly of potato subjected to the peeling process, does not endanger human health. Although contents of glycoalkaloids and nitrates in potatoes assigned to industrial processing is not a risk for human health, a lot of companies all over the world verify toxic compounds in potato as a matter of routine, especially glycoalkaloids, because cultivation, harvesting and storage conditions together with properties of a particular variety, as well as the size of tubers, can cause increase of the contents of these compounds over the limits regarded as safe for human health (Maga, 1980; Smith et al., 1996).

Some authors (Cieślik, 1998; Friedman & McDonald, 1997; Mondy & Gosselin, 1988; Pęksa, Gołubowska, Rytel, Lisińska, & Aniołowski, 2002) have investigated contents of glycoalkaloids in selected semi potato products as well as in ready products, such as: unpeeled cooked potato, baked potato, potato cooked in microwave oven or fried as chips. They observed that changes in the contents of these compounds are mainly the result of the peeling process. However, there is no information about changes of glycoalkaloids and nitrates contents in potato tubers during fried products processing, including chips.

The purpose of this investigation was to determine changes in contents of glycoalkaloids, specifically α-solanine and α-chaconine, and nitrates in potatoes of two varieties during chip processing.

## 2. Materials and methods

### 2.1. Raw material

Samples of tubers of two potato varieties: middle-early Karlena and middle-late Saturna were collected from six stages of a chip processing line. Samples were taken three times from each of the following stages: 1, potato unpeeled; 2, potato after peeling; 3, potato after slicing, 4, slices after washing; 5, slices after blanching; 6, chips, not spiced.

### 2.2. Potato sample preparation for glycoalkaloids analysis

Directly after being taken from the chip processing line, potato tuber samples were cut in 1 cm thick slices and freeze-dried. Samples of chips were defatted and then freeze-dried. The dry material obtained, after being ground in an electric grinder, became the material used for defining the contents of α-solanine and α-chaconine.

### 2.3. Apparatus

A high-pressure liquid chromatograph HPLC was used (Varian, Walnut Creek, CA, USA) equipped with a type 310 UV detector and a computer system monitoring the chromatograph (Varian Chromatography Systems). A Microsorb NH2 (25 × 46 cm LD) analytical column (Rainin Instrument, Woburn, MA, USA) was used.

### 2.4. Conditions of glycoalkaloids separation

A 50:20:30 (v/v/v) mixture of tetrahydrofuran (THF) (Merck, Darmstadt, Germany), acetonitrile (ACN) and water plus 1.02 g/l $KH_2PO_4$ was used as an eluent. The process was carried out at the temperature of 35 °C, a flow rate of 2 $cm^3$/min and pressure of 112 atm, with detection at 208 nm.

### 2.5. Sample preparation for chromatographic analysis

The freeze-dried material (1 g) was homogenised with 4 $cm^3$ of 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 an SPE column (Bond Elut C18, 500 mg, 6.0 $cm^3$, Varian). Glycoalkaloids were rinsed with methanol and evaporated to dryness in vacuo at a temperature of 50 °C. The residue formed was dissolved in 1 $cm^3$ of 50:20:30 (v/v/v) THF/ACN/$H_2O$. Before application to the column, the sample was cleaned up using a 0.45 μm filter. The injected volume was 10 μl.

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 volumes, containing from 1 to 50 μg/$cm^3$ of either α-solanine or α-chaconine, were injected.

### 2.6. Analytical methods

The dry matter content in fresh and freeze-dried materials was determined by drying at 102 °C until constant weight was achieved (AACC, 1995). The quantities of α-solanine and α-chaconine were determined by the method of Saito, Horie, Hoshino, and Nose (1990). The nitrate content ($NO_3^-$ ions) in fresh samples of potato and in defatted chips was determined using an RQflex reflectometer (Merck). All analyses were done twice.

### 2.7. Statistical analysis

The results obtained in the experiment were subjected to statistical calculations according to the Statgraphics program. Two-way analysis of variance was used and the Duncan test for determining, the significance of the influence of potato variety and the stage of chip

processing line on the contents of α-solanine, α-chaconine and nitrates in the studied samples.

## 3. Results and discussion

During chips production significant changes in contents of glycoalkaloids in manufactured raw material occurred.

As shown in Table 1, potato tubers of the Saturna variety contained more total glycoalkaloids in dry matter (TGA) (16.5 mg/100 g) in comparison to the Karlena variety (12.9 mg/100 g) before the peeling process. The amounts were remarkably lower than the generally allowable dose of TGA in potato, which is 20 mg/100 g of fresh mass and even lower than the amount of 10 mg/100 g of these compounds, determined as safe by JOINT FAO/WHO Expert Committee on Food Additives in 1992 (JECFA, 1992). Potato varieties available in the market usually contain less glycoalkaloids than widely accepted limits. However, about 2–9% of samples exceed the limits mentioned above (Smith et al., 1996). Together with unfavourable cultivation and storage conditions, some varieties may accumulate up to 30 mg of TGA/100 g. One of the varieties of that sort was, for instance, Lenape variety (Sinden et al., 1984).

The next stages of chips processing caused a decrease of glycoalkaloid contents, both of α-chaconine and of α-solanine, in studied potato samples (Figs. 1 and 2). During the peeling process, 22–28% of the initial amount of glycoalkaloids present in studied tubers was removed. The peeling process should remove a significant part of these compounds because they are accumulated mainly in the potato peel and in the outside layer (1.5 mm) of the potato tuber. Depending on the size of the tuber, peeling technology and potato variety, the decrease of glycoalkaloid contents may reach the level of 80–96%, 50–70% and in the case of incomplete peeling the level of 20–35% (Bushway, Bureau, & McGann, 1983; Cieślik, 1998; Friedman & McDonald, 1997; Salunkhe, Kadam, & Jadhav, 1991). In peeled tubers, there is 1–10 mg of TGA/100 g (Leszczyński, 1994; Salunkhe et al., 1991; Smith et al., 1996). However, the peeling process may prove insufficient when processing bitter tasting potato varieties which accumulate high amounts of glycoalkaloids (Haddadin, Humeid, Quaroot, & Robinson, 2001; Smith et al., 1996). After the peeling process, in tubers of the studied varieties, 10–12 mg of TGA in dry matter remained (Table 1), including 7–8 mg of α-chaconine and about 3–3.5 mg of α-solanine (Figs. 1 and 2).

Table 1
Total glycoalkaloids content (mg/100 g d.m.) in potatoes of two varieties during chip processing

| Technological stage | Variety | |
|---|---|---|
| | Karlena | Saturna |
| | Total glycoalkaloids (mg/100 g d.m.) | |
| Potato unpeeled | 12.9d | 16.5c |
| Potato after peeling | 10.1cd | 11.8 |
| Potato after slicing | 8.21c | 8.53c |
| Slices after washing | 5.25b | 4.87b |
| Slices after blanching | 3.83b | 3.72b |
| Chips | 2.35a | 2.26a |

a–d – mean values of total glycoalkaloids contents with different letters differ significantly at $p \leqslant 0.05$.

Further significant decrease both of α-chaconine and α-solanine in comparison to peeled potato was observed after the slicing process, mainly in tubers of Saturna variety, from 8.30 to 6.10 mg of α-chaconine/100 g of dry matter (26%) and from 3.50 to 2.40 mg of α-solanine/100 g of dry matter (31%). Washing, caused a decrease of the amount of α-chaconine to the level of 3.7 mg/100 g of dry matter (Saturna variety) (55%) and to 4.9 mg/100 g of dry matter (Karlena variety). α-Solanine, depending on variety, was reduced to 1.16 and 1.30 mg/100 g of dry matter, i.e., of about 62% on average in comparison to peeled potato. The total amount of glycoalkaloids in potato slices after washing was of 5 mg/100 g of potato dry matter, which is 60–70% of the initial amount (Table 1). Some authors' investigations (Cieślik, 1998; Mondy & Gosselin, 1988; Salunkhe et al., 1991) show that changes of TGA contents in edible potatoes during processing are mainly due to the process of peeling the tubers, while the degree of cutting as well as most methods of cooking do not affect significantly the content of TGA in semi and ready potato products. The investigation carried out confirmed these observations. The process of blanching potato slices did not cause any significant changes in glycoalkaloids contents in studied potato samples (Table 1, Figs. 1 and 2). However, a significant decrease of the content of these compounds (77–80%) depending on potato variety, in comparison to peeled potato and 82–86% in comparison to unpeeled tubers was observed after the process of frying. Fried chips contained 0.7 mg of α-solanine and about 1.55 mg of α-chaconine/100 g of dry matter, i.e., about 2.3 mg of glycoalkaloids altogether in dry matter of chips obtained from both potato varieties. These remain within the lower limits of the accepted ranges of the contents of these compounds in chips (2.3–18 mg/100 g of products), quoted by some authors (Friedman & McDonald, 1997; Smith et al., 1996). Salunkhe et al. (1991), comparing changes of TGA contents in potatoes under the influence of some processes, such as: frying, baking, microwaving, boiling, observed that only the process of frying caused a decrease of the contents of these compounds. Some other authors (Cieślik, 1998; Friedman & McDonald, 1997; Smith et al., 1996) are of a similar opinion. According to these authors, the

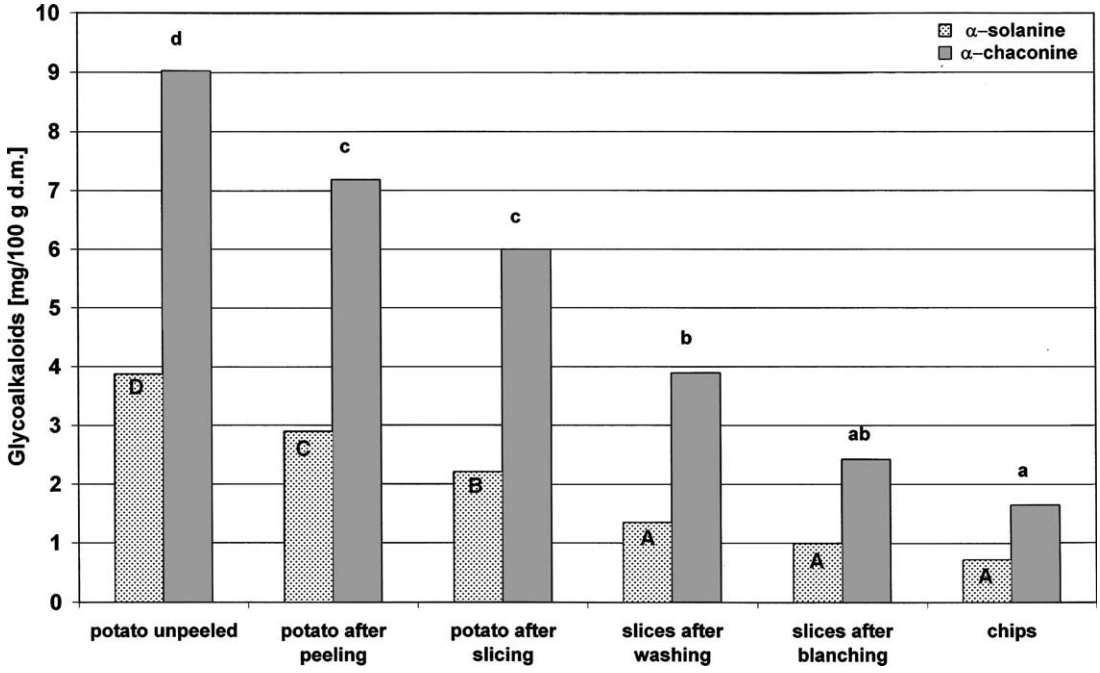


Fig. 1. The contents (mg/100 g d.m.) of α-chaconine and α-solanine in potato of Karlena variety during chips processing. (a–d) – mean values of chaconine contents with different letters differ significantly at $p \leqslant 0.05$. A–D – mean values of solanine contents with different letters differ significantly at $p \leqslant 0.05$.

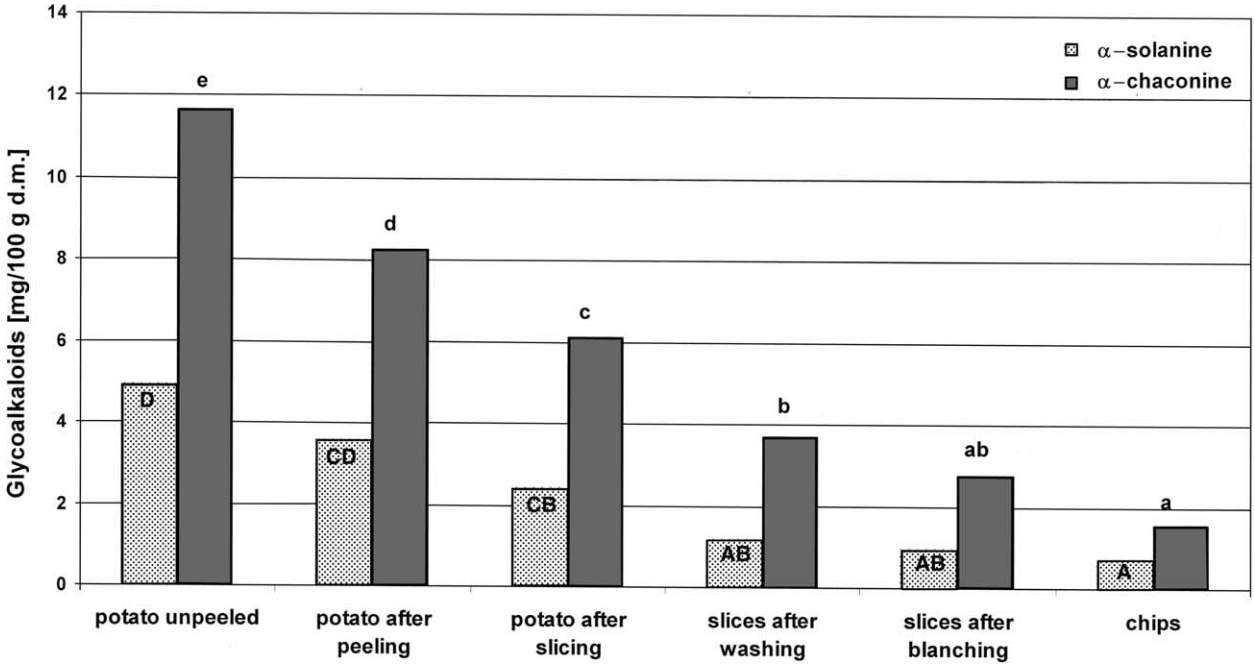


Fig. 2. The contents (mg/100 g d.m.) of α-chaconine and α-solanine in potato of Saturna variety during chips processing. (a–e) – mean values of chaconine contents with different letters differ significantly at $p \leqslant 0.05$. A–D – mean values of solanine contents with different letters differ significantly at $p \leqslant 0.05$.

process of frying sliced potato facilitates oil penetration and high temperature action (170–180 °C), resulting both in washing away and in decomposition of about 40% of glycoalkaloids contained in potato.

The ratio of the contents of α-chaconine to α-solanine during the potato processing was of about 2.5:1 and was maintained at a similar level during the whole technological process. However, the technological treatments

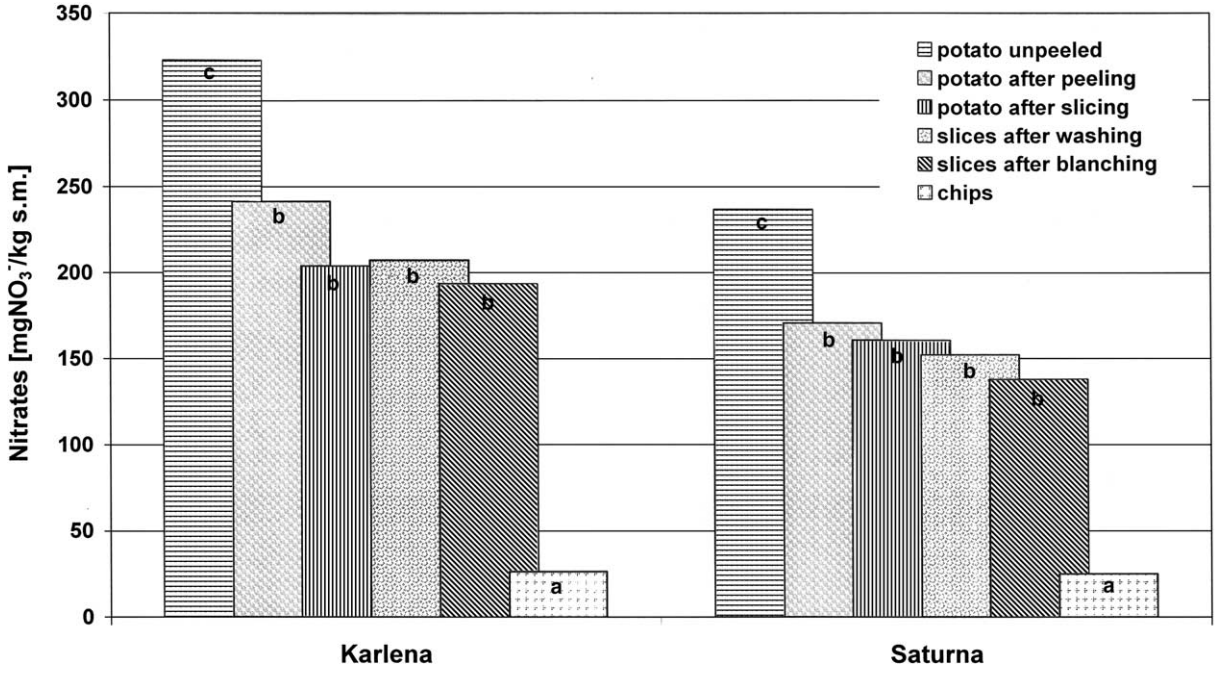


Fig. 3. Nitrates contents (mg $NO_3^-$/kg d.m.) in potato of two varieties during chips processing. (a–c) – mean values of nitrates contents with different letters differ significantly at $p \leqslant 0.05$.

applied, particularly slicing, washing and peeling, resulted in a higher loss of α-solanine than of α-chaconine.

Potato belongs to a group, of plants that usually accumulate low or average amounts of nitrates in their tubers. Their amounts oscillate in wide ranges of 40–740 mg of $NaNO_3$/kg of wet basis. However, the content of nitrates on average does not exceed 300 mg/kg (Cieślik et al., 1990; Leszczyński, 1994, 2000; Lisińska & Leszczyński, 1989). Potato tubers of Saturna and Karlena varieties used in the experiment contained small amounts of nitrates; 236 mg of $NO_3$/kg of dry matter and 322 mg of $NO_3$/kg of dry matter (Fig. 3), i.e., below 100 mg of $NO_3$/kg of wet basis. Technological treatments applied in the process of chips production significantly reduced the amount of nitrates in semi products and in ready potato products. Most of these compounds were removed during the process of peeling the tubers (25–28%) and the process of frying (ca. 85–89% depending on potato variety, in comparison to peeled potato). The process of slicing, washing and blanching together caused a decrease of the amount of nitrates by about 19–20%, depending on potato variety (Fig. 3). Chips obtained in the experiment contained on average 25.5 mg of $NO_3$/kg of dry matter, i.e., 8–11% of their initial content in potato tubers. According to Cieślik (1992), the, processes of peeling the tubers, cutting and boiling in water, makes it possible to remove significant amounts of nitrates contained in them, however, not more than 70%. Nitrates present in potatoes are mostly found in potato peel and immediately below it. They are compounds easily soluble in water and are not heat resistant. Therefore, some stages of chips production, such as: peeling, slicing and washing, as well as the process of frying at high temperature (180 °C), allow removal of most of nitrates contained in the potato (Cieślik, 1992; Hill, 1999; Leszczyński, 1994, 2000).

## 4. Conclusions

The stages of chip processing, caused a significant decrease of glycoalkaloids and nitrates contents in examined potatoes of Saturna and Karlena varieties. The ratio of α-chaconine to α-solanine contents during potato processing was maintained at a similar level during the whole process of chips production and was about 2.5:1. Significant decrease of glycoalkaloids, particularly α-solanine, and nitrates contents during chips production was observed. The greatest influence on the decrease of glycoalkaloids contents was through the processes of peeling, slicing, washing and frying, and on the decrease of nitrates contents, the processes of peeling and frying. Obtained chips contained 14–18% of the amount of glycoalkaloids and 8–11% of the amount of nitrates present in the raw material.

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