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The effect of industrial potato processing on the concentrations of glycoalkaloids and nitrates in potato granules

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ABSTRACT

The aim of this study was to determine the effects of the different stages of industrial processing of potatoes, on the content of glycoalkaloids (chaconine and solanine) and nitrates in the raw material, intermediates, finished granules and waste products.

The material used for the study included samples of raw tubers, semi-finished products and finished products taken directly from 8 points in the technological line for the production of potato granules, and 3 points from the waste product line. The samples were collected three times within two years of research (in 2009 and 2010) from the following places: 1/unpeeled potato, 2/potato after peeling, 3/potato after blanching, 4/potato after cooling, 5/steamed potato, 6/pneumatically dried potato, 7/product after fluidization drying, 8/granulated product, and waste products: 9/peels, 10/waste after air drying and 11/after fluidization drying.

In the raw material, intermediates, finished granules and waste products, the concentrations of glycoalkaloids (α-chaconine and α-solanine) were determined using an HPLC method, and nitrates were determined colorimetrically using an RQflex analyser.

It was found that the industrial processes of potato granules significantly decreased the concentration of glycoalkaloids (chaconine and solanine) and nitrates in intermediates and finished products when compared to raw material. The highest decrease in glycoalkaloids was caused by peeling (50%) and blanching (63%). The concentration of nitrates decreased the most after thermal processes – after blanching a decrease of 20% and after air drying – by 50%. The dehydrated potato granules contained on average 14% of the initial quantity of glycoalkaloids and 48% of nitrates. High content of toxic compounds was found in potato peels but dry wastes after pneumatic drying or after fluidization contained proportionally low contents of those compounds.

1. Introduction

Drying is one of the oldest methods of food preservation and an important factor in production technology (Bondaruk, Markowski, & Błaszczak, 2007; Vadivambal & Jayas, 2007). Perishable goods, such as raw vegetables or fruit, benefit from dehydration in many ways, primarily in substantially reducing losses resulting from raw material storage (up to 20%), lowering water activity of the material, slowing down many enzymatic reactions and microbial growth, which in effect permits much longer storage than fresh material (Lisińska & Leszczyński, 1989, 391 pp.).

Drying provides a whole range of different potato products, i.e.: dices, groats, granules, potato flakes or flour. These products should all have high nutritional value, low content of toxic compounds and good organoleptic characteristics. Dehydrated potato products and intermediates obtained during the processing of potatoes into granules contain the same compounds as the raw material but in different quantities and proportions. Processing into refined products, including those dehydrated, usually uses potato varieties with a low tendency to accumulate anti-nutritional or toxic compounds.

Natural toxic compounds in potato include glycoalkaloids – α-chaconine and α-solanine. The synthesis of these compounds by the potatoes depends on genetic factors, environmental conditions (weather prevailing during the growing season, rainfall, sunshine), and storage conditions (Donald, 2008; Leszczyński, 2000; Lisińska & Leszczyński, 1989, 391 pp.; Lisińska, Pęksa, Kita, Rytel, & Tajner-Czopek, 2009; Wünsch & Munzert, 1994; Zgórska, Czerko, & Grudzińska, 2006). Potatoes should contain less than 10 mg per 100 g^{-1}, as a concentration as low as 11 mg per 100 g^{-1} results in an undesirable acrid aftertaste (Knuthsen, Jensen, Schmidt, & Larsen, 2009; Leszczyński, 2000; Pęksa, Gołubowska, Rytel, Lisińska, & Aniołowski, 2002; Speijers, 1998, pp.43–47). Natural anti-

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nutritional compounds in potato also include nitrates. Potato tubers generally contain less than 200 mg NO_3^{-1} kg^{-1}, a medium level compared to other vegetables that may accumulate more than 300 mg 100 g^{-1}, such as lettuce (Hill, 1999; Murawa, Banaszkiewicz, Majewska, Błaszczyk, & Sulima, 2008). Their concentration in tubers depends on the cultivation of the potatoes, and mainly on the intensity and frequency of nitrogen fertilization, climatic conditions and type of storage (Cieślik, 1995; Rytel, Pęksa, Tajner-Czopek, Kita, & Lisińska, 2011).

Processes utilized during the production of potato granules can have different effects on the content of anti-nutritional and toxic compounds, mainly due to the nature of these compounds and the distribution in the tuber. Initial processes used during the production of potato granules, including the washing and peeling of tubers, result mainly in a decrease in glycoalkaloids. As they are located mostly in or just beneath the skin, their content may be reduced by 50% on average (Friedman & McDonald, 1997; Pęksa, Gołubowska, Aniołowski, Lisińska, & Rytel, 2006; Rytel, Gołubowska, Lisińska, Pęksa, & Aniołowski, 2005; Tajner-Czopek, Jarych-Szyszka, & Lisińska, 2008; Valkonen, Keskitalo, Vasara, & Pietila, 1996). Thermal processes, such as blanching or drying, may contribute to leaching of compounds that dissolve well in water, mostly nitrates (Cieślik, 1995). According to Becka, Micka, and Vockal (1992) and Cieślik (1992) blanching as well as cooking influence on nitrates decreases on the level of about 20% when compared to raw material. Glycoalkaloids, due to their thermostable nature, are more resistant to high temperatures (Friedman, 2003, 2006). Many authors (Friedman, 2006; Friedman & Dao, 1992; Knuthsen et al., 2009; Valkonen et al., 1996) state that culinary processes, such as cutting, blanching, cooking and baking in a much lower degree in comparison to peeling, decrease TGA contents in potatoes.

The production of dehydrated potato products results in many different waste products, some of which, such as waste from peeling or drying, contain ingredients that could be used as food additives, and not only in animal feed as has been the case so far. It seems necessary to thoroughly examine the various waste products of industrial potato processing, not only in terms of nutritional but also anti-nutritional compounds.

The aim of this study was to determine the effects of the different stages of industrial processing of potatoes, on the content of glycoalkaloids (chaconine and solanine) and nitrates in the raw material, intermediates, finished granules and waste products.

2. Material and methods

2.1. Raw material

The material used for the study included samples of raw tubers, semi-finished products and finished products taken directly from 8 points in the technological line for the production of potato granules, and 3 points from the waste product line. The samples were collected three times within two years of research (in 2009 and 2010) from the following places: 1/unpeeled potato, 2/potato after peeling, 3/potato after blanching, 4/potato after cooling, 5/steamed potato, 6/pneumatically dried potato, 7/product after fluidization drying, 8/granulated product, and waste products: 9/peels, 10/waste after air drying and 11/after fluidization drying. There were prepared 1 kg samples from each stage of the technology line for glycoalkaloids (α-chaconine and α-solanine) and nitrates contents.

2.2. Potato sample preparation for analysis

The samples from the technological line, from numbers 1 to 5, and peelings, were crushed and freeze-dried (apparatus of Edwards firm). The dried samples were ground in an electric grinder, and together with samples 6, 7, 8, 9, 10, 11 were used as material for the determination of α-solanine, α-chaconine and nitrates.

2.3. The concentrations of α-solanine and α-chaconine

2.3.1. Apparatus

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

2.3.2. Conditions of glycoalkaloid separation

A mixture of tetrahydrofuran (Merck, Germany), acetonitrile and water 50:20:30 + KH_2PO_4 (1.02 g) per liter was used as an eluent. The process was carried out at a temperature of 35 °C, with a speed of flow of 2 cm^3 min^{-1} and pressure of 11.3 MPa, applying a light wavelength of 208 nm.

2.3.3. Sample preparation for chromatographic analysis

The dried material (1 g) was homogenized with 4 cm^3 of water and 30 cm^3 of methanol (Labscan, Ireland) 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 extract was cleaned up on the SPE column (Bond Elut C18; 500 mg; 6.0 cm^3, Varian, USA). Glycoalkaloids were rinsed with methanol and evaporated to dryness in a vacuum at a temperature of 50 °C. The resultant residue was dissolved in 1 cm^3 of THF:ACN:H_2O – 50:20:30. Before application into the column, the sample was cleaned using 0.45 μm filters. The volume of the injection 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. Standard solution was dissolved to obtain samples containing from 1 to 50 μg/cm^3 of both α-solanine and α-chaconine. On the column 10 μl of solution was injected.

Samples were prepared with the agreement of the methodology described by Pęksa et al. (2002) and Saito, Sanford, and Webb (1990).

2.4. The content of nitrates

A reflectometric method with test strips was used, at a measurement range from 5 to 225 mg NO_3^{-1} kg^{-1}. According to the principle of reflectometry (remission photometry), the reflected light from the strip was measured. In classical photometry, the difference in the intensity of emitted and reflected light allows a quantitative determination of the concentration of specific analysis.

2.4.1. Sample preparation for nitrates analysis

Nitrate concentrations were determined by reflectometry using a Rqflex analyser (Merck). Determinations were made in 20 g of distilled water solution containing 5 g of a dry sample. In the solution nitrate concentrations using test strips was measured. In agreement with methodology described by Rytel et al. (2005).

2.5. Analytical methods

The nitrate content of the potato tubers was determined colorimetrically in the potato tubers, intermediates and finished products (Rytel et al., 2005). The quantities of α-solanine and α-chaconine were determined using the method of Pęksa et al. (2002) and Saito et al. (1990). All the analyses were carried out twice.