PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 3 (6): 357-361, 2004

Effect of Culinary Processes on the Content of Nitrates and Nitrites in Potatoe

Waclaw Mozolewski and Stefan Smoczyñski
University of Warmia and Mazury, Institute of Commodities Science and Quality Evaluation,
10-957 Olsztyn, Pl. Cieszyñski 1, Poland
E-mail: mozol@uwm.edu.pl

Abstract: The effect of potato culinary processing on the changes in the content of nitrates and nitrites was determined. The experimental material were potato tubers of Ibis, Mila and Muza varieties with elevated nitrate (175.4 - 250.7 mg $NO_3 \cdot kg^{-1}$) and nitrite (1.7 - 4.3 mg $NO_2 \cdot kg^{-1}$) content. The losses of nitrites occurring after the preliminary processing (washing, manual peeling and rinsing) were greater than nitrates and ranged from 25 to 75% and from 18 to 40%, respectively. Differences in the losses of these compounds were variety-dependent. During thermal processing of potato tubers with different methods, the losses of these compounds varied and were significantly greater for nitrites (61-98%) than for nitrates (16-62%). The greatest decrease in the content of nitrates was found for deep fried potatoes and for boiling in water. The losses of nitrates are significantly higher in peeled potato tubers subjected to thermal processing with direct contact of the product with water (p=0.05) than in steam or oil.

Key words: Nitrates, nitrites, potatoes, culinary processes, food safety

Introduction

Nitrates naturally occur in plant-based food. Plants typically uptake nitrogen from the environment and assimilate it to produce amines and amides. The nitrate content in plants increases with increased doses of mineral nitrogen fertilization (Hlusek *et al.,* 2000; Kolbe, 1996: Voronina, 1997). However, nitrate content in consumable plant organs is small and should not raise concern provided that the recommended fertilization and harvest terms of the original plants are observed (Frydecka-Mazurczyk and Zgórska, 2000; Galler, 1997; Mazurczyk and Lis, 2003; Mikos-Bielak *et al.*, 2001; Rembialkowska *at al.,* 2001). Studies completed in different countries confirm that nitrates and nitrites contents in vegetables and potatoes vary extensively and are determined by vegetable variety, harvest term, country and farm type (Dich *at al.,* 1996; Gaballa, 2000; Galler, 1997; Hamouz *at al.,* 1999; Rembialkowska *et al.,* 2001; Zhong *et al.,* 2002; Chung *et al.,* 2003; Hambridge, 2003). The nitrates and nitrites contents are largely diversified and according to varied sources (Chung *et al.,* 2003; Cieslik, 1997; Hamouz *et al.,* 1999; Markowska *et al.,* 1995; Mazurczyk *and* Lis, 2003; Rembialkowska *et al.,* 2001; Rutkowska, 2001; Voronina, 1997) range from 4.0 to 840 mg $NaNO_3$/kg and from 0.00 to 3.18 mg $NaNO_2$/kg, respectively. Among all vegetable groups, potatoes accumulate only small amounts of nitrates and nitrites. It is estimated that on average 65-75% of nitrates consumed in a diet come from vegetables, including potatoes (Czarniecka-Skubina *et al.,* 2001; Markowska *et al.,* 1995) while Dich *et al*. (1996) report that the intake of nitrates and nitrites with vegetables is over 90% of the total consumption of these compounds. Marin *et al*. (1998) report that up to 14.4% of nitrates and 9.2% nitrites consumed in a daily diet originate from potatoes.

In the alimentary tract, nitrates can be reduced to nitrites and further take part in forming cancerogenic compounds. Excessive accumulation of nitrates and nitrites in some vegetables is not as worrying as the direction of their transformation in a human body (Galler, 1997; Dich, 1996; Mevissen, 1997). Considering the significant potato consumption in Poland (100 kg yearly per person) they may become an important source of these compounds because on 1 May 2004 (Poland's accession to the EU) the limiting levels for nitrates and nitrites were abolished. These undesirable compounds in vegetables are limited by the European Commission (Commission Regulation, 2001) in spinach and lettuce whose consumption, in comparison to the "old" Member States of the EU, is low. However, the introduced Good Hygenic Practice (GHP) and Good Manufacturing Practice (GMP) are compulsory and aim at the minimalization of impurity levels in food production and processing.

Due to the progress and availability of varied culinary techniques in both the catering industry and the households, increasingly more frequently varied techniques of potato preparation are used: steaming in convectional-steam ovens, boiling in acuthermal pots, boiling in microwave ovens in water and frying in deep fryers as French fries or chips. To obtain high potato sensory quality and maintain its nutritional value (most of the nutritional components are located under the skin) whole tubers are thermally treated, i.e. with no peeling (baking, steaming or boiling). Nitrates are distributed unevenly in a tuber but in the largest amounts occur in the skin and just under it (Marin *et al.,* 1998;

Golaszewska and Zalewski, 2001). However, some studies indicate that nitrites are evenly distributed in a potato tuber (Marin *et al.,* 1998). The technological process can have an effect on the remaining amount of these compounds in a product prepared for consumption. The aim of this paper was to determine the changes in the content of nitrates and nitrites occurring during potato culinary processing.

Materials and Methods

Materials: Tubers of three potato varieties: Ibis, Mila and Muza cultivated in the Agricultural Experimental Station in Tomaszkowo, University of Warmia and Mazury in Olsztyn, were used for the experiment. To obtain a high level of nitrates and nitrites in the material, the experimental potatoes were cultivated with the use of the maximum permissible nitrogen fertilization level of 150 kg $N \cdot ha^{-1}$. Each potato variety was cultivated over 5 experimental fields in parallel. After harvest, the potatoes of the same variety were combined together. Samples were taken of calibrated potatoes of short diameter of 5-5.5 cm and long diameter of about 6 cm. Before culinary process, the content of nitrates and nitrites was determined and the results are given in Table 1.

Applied culinary techniques: The experimental tubers were thoroughly washed, dried, manually peeled and rinsed. The following thermal processes were used:
traditional boiling in water: the tubers were submerged in boiling water and boiled for 30 minutes until soft;
boiling in a microwave oven: the tubers were submerged in water in a glass bowl. A constant potato to water mass was used: 1:7.5 and treated 7 minutes at maximum power of 1500 W;
boiling in acuthermal pots: the tubers were placed in a cold Zepter pot, 30-35 cm^3 of water was added and everything was heated with a lid for about 35 min. maintaining the thermoregulator indicator at the maximum position;
steaming in a convection-steam oven: the tubers were placed on stainless steel trays on the middle shelf of a hot G-10/1 Zanussi oven. The potatoes were steamed for 20 min at a humidity of 99% and at 99°C;
frying: untreated potato strips 0.8x0.8x5.0 cm were fried in rapeseed oil heated to 160°C for 6 min in an electric Philips deep fryer. The potato-to-oil ratio was constant and was 1:40. After frying, the French fries were placed on a blotting paper to remove the excess oil.
The obtained samples were cooled in a shock refrigerator, disintegrated mechanically and analyzed.

Methods: The content of nitrites was determined using a spectrophotometric method after colour reaction with Griess reagent. Nitrates were reduced to nitrites with cadmium powder and measured spectrophotometrical (Polish standard method, 1992).
The technological and chemical examinations were performed in three replications. The results were statistically analyzed employing a single-factor analysis variance. The significance of differences was estimated by the SNK test (Student-Newman-Keuls). The statistical analysis was performed at the significance level of $p=0.05$.

Results and Discussion

The experimental results indicate that the content of nitrates and nitrites in the analyzed material was high and varied (Table 1). This variation was determined by both the high nitrogen fertilization level applied and the potato variety used (which accumulate these compounds to different degrees). The lowest amounts of nitrates (175.4 ± 61 mg $NO_3 \cdot kg^{-1}$) was contained by Ibis variety tubers, while the largest amounts (250.7 ± 5,0 mg $NO_3 \cdot kg^{-}1$) were found in Mila variety. The content of nitrites in the tubers of the analyzed potatoes varied and ranged from 1.7 ± 0.09 mg $NO_2 \cdot kg^{-1}$ for Muza tubers to 4.3 ± 0,08 mg $NO_2 \cdot kg^{-1}$ for Ibis tubers. The above results indicate that due to high nitrogen fertilization levels, potatoes available to consumers have considerable and varied contents of nitrates and nitrites. The high content of these compounds in the potatoes limits their consumption value (Cieslik, 1997). In the human body these compounds can be transformed into harmful nitrosamines (Galler, 1997; Mevissen, 1997).
A significant decrease in the content of nitrates and nitrites was obtained after the preliminary preparation. The loss of these compounds ranged from 18% (Mila) to 40% (Muza) (Fig. 1). These results are similar to those obtained by Czarniecka-Skubina and Golaszewska (2001), who found a 36% nitrates decrease after potato peeling where the peel was 2 mm. Similar results (35%) were also obtained by Golaszewska and Zalewski (2001). However, significantly lower nitrates losses (6.3%) after potato peeling were reported by Gaballa (2000). This discrepancy can be explained by Czarniecka-Skubina and Golaszewska (2001) who showed that the potato skin contains the highest nitrate concentration and its content decreases (approximately 3-fold) towards the centre of the potato tuber. The experiments therefore indicate that the amount of nitrates removed in the preliminary processing depends on the method of peeling and the thickness of the peel removed with the skin.
Preliminary processing produced considerably greater nitrites losses. Fig. 2 demonstrates that potato peeling decreases the nitrite content by 25, 60 and even 75% for Muza, Mila and Ibis potato tubers, respectively. The nitrate content in potatoes is particularly harmful due to the potato presence in the daily diet. Since the presence of nitrates and nitrites in a diet is harmful to human health, the FAO/WHO Expert Committee (2002) established the Acceptable Daily Intake (ADI). The limit

Table 1: Content of nitrates (mg $NO_3 \cdot kg^{-1}$) and nitrites (mg $NO_2 \cdot kg^{-1}$) in potato tubers after harvest

Ibis		Mila		Muza	
Nitrates	Nitrites	Nitrates	Nitrites	Nitrates	Nitrites
x ± SEM	x ± SEM	x ± SEM	x ± SEM	x ± SEM	x ± SEM
175.4± 6.1	4.30±0.06	250.7±5.0	3.00±0.03	234.0±3,6	1.70±0.09

Table 2: Effect of culinary processing on content of nitrates (mg $NO_3 \cdot kg^{-1}$) in potato tubers

Cooking method	Ibis	Mila	Muza
	x ± SEM	x ± SEM	x ± SEM
No cooking	$130.1^a \pm 4.1$	$205.3^a \pm 3.6$	$140.3^a \pm 2.6$
In microwave oven in water	$94.6^b \pm 1.9$	$151.7^b \pm 4.4$	$105.5^b \pm 2.3$
In pot with water	$78.9^c \pm 3.4$	$131.5^b \pm 6.9$	$58.8^c \pm 1.0$
In acuthermal pot	$95.0^b \pm 1.4$	$141.7^b \pm 1.0$	$107.4^b \pm 2.0$
In convectional-steam oven in stem	$109.4^b \pm 3.7$	$147.8^b \pm 3.7$	$110.8^b \pm 1.3$
Frying	$65.1^d \pm 2.1$	$94.4^c \pm 1.9$	$53.3^c \pm 1.4$

Differences between the values denoted with the same letter (a, b, c, d) in a column are statistically insignificant at p=0.05

Table 3: Effect of culinary processing on content of nitrites (mg $NO_2 \cdot kg^{-1}$) in potato tubers

Cooking method	Ibis	Mila	Muza
	x ± SEM	x ± SEM	x ± SEM
No cooking	$1.05^a \pm 0.04$	$1.19^a \pm 0.02$	$1.30^a \pm 0.06$
In microwave oven in water	$0.04^c \pm 0.00$	$0.04^d \pm 0.01$	$0.11^c \pm 0.01$
In pot with water	$0.03^c \pm 0.01$	$0.02^d \pm 0.01$	$0.22^c \pm 0.01$
In acuthermal pot	$0.26^b \pm 0.01$	$0.32^b \pm .0.10$	$0.50^b \pm 0.01$
In conventional-steam oven in steam	$0.21^b \pm 0.02$	$0.18^c \pm 0.01$	$0.25^c \pm 0.02$
Frying	$0.25^b \pm 0.01$	$0.16^c \pm 0.01$	$0.23^c \pm 0.02$

for nitrates is 0-3.7 mg NO_3 and for nitrites 0-0.07 mg NO_2 per kg of body mass.

A further phase of the potato culinary process which has an effect on the content of nitrates in the tubers is thermal processing. After the application of varied boiling methods, a significant (p=0.05) decrease in the nitrate content was obtained in the experimental tubers (Table 2). From among the potato boiling processes applied, the highest nitrate losses (36-58%) were observed after the boiling of peeled potatoes in a pot. For example, Muza potatoes after boiling in water contained 58.8 ± 1.0 mg $NO_3 \cdot kg^{-1}$, which is approx. 40% of the content after the preliminary processing (140.3 ± 3.6 mg $NO_3 \cdot kg^{-1}$). For the non-peeled potatoes (Table 1), boiling potatoes in water removed only 25% of the nitrate content. Nitrates are highly-soluble in water and elute to water while potato boiling. For potato preparation in steam (an acuthermal pot, a convection-steam oven) and in a microwave oven, the nitrate content decreases were also significant (p=0.05) when compared to the raw material but the removed amounts were lower than in the potatoes traditionally boiled in a pot with water. Similar results were obtained by Markowska *et al.* (1995) and Gaballa (2000). A significantly lower nitrate removal was reported by Czarniecka-Skubina and Golaszewska (2001) and Golaszewska and Zalewski (2001). The discrepancy in the results is likely to have been determined by different original nitrate content and amount of water used for boiling. The differences in the content of nitrates in Mila potato samples subjected to different boiling methods were statistically insignificant, which could have been determined by variety traits.

Among the applied thermal processing techniques (Table 2), deep fried potatoes produced the highest (p=0.05) nitrate losses. Losses of nitrates from deep fried potatoes were considerable and ranged from 50% to 62% for French fries obtained from Ibis and Muza peeled potato tubers. This indicates that heat treatment in significantly higher temperatures (approx. 160-180°C) can degrade nitrates into other compounds. It is also likely that when frying, highly water-soluble nitrates migrated outside the product and were captured by steaming water contained in the product.

The results presented in Table 3 demonstrate that potato thermal processing considerably reduces the content of nitrites. The nitrite losses were statistically significant (p=0.05). The highest nitrite loss from potatoes occurred when boiled in water both in a pot and in water in a microwave oven (the "wet" method). The nitrite losses in potatoes boiled under these conditions ranged from 82% (Muza potato tubers) to 98% (Mila potato tubers) when compared to the raw potatoes. For example, peeled raw Mila potatoes contained 1.19 mg $NO_2 \cdot kg^{-1}$, whereas after boiling in water they contained only 0.04 mg $NO_2 \cdot kg^{-1}$ (processing in a microwave oven) and 0.02 mg $NO_2 \cdot kg^{-1}$ (traditional boiling in a pot).

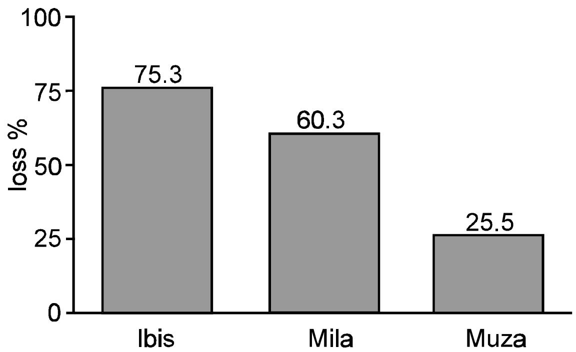

Fig. 1: Nitrate loss during potato preliminary processing

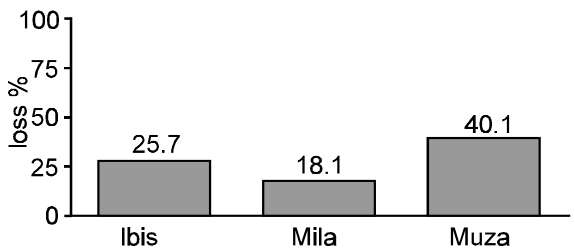

Fig. 2: Nitrite loss during potato preliminary processing

The nitrate losses during the boiling of experimental potatoes are similar to those reported by Markowska *et al*. (1995) and Marin *et al*. (1998). Different results were obtained by Gaballa (2000), who pre-boiled potatoes in water at 100°C for 3 min. This author found higher nitrite losses (59.6%) than nitrate losses (15.4%). It seems that the nitrite losses in that experiment were determined by the period of potato processing in water, which was largely shorter in the experiments of Gaballa (2000).

Somewhat lower, however significant (p=0.05), losses of nitrites were observed in the present experiment for potato steaming (a convection-steam oven and an acuthermal pot) and deep frying potato strips. Thermal processes such as steaming in a convection-steam oven and in an acuthermal bottom pot, as well as in a deep fryer applied to Ibis potatoes produced a very similar nitrites reduction. Raw tubers of this potato variety contained 1.05 mg $NO_2 \bullet kg^{-1}$ and after thermal processing (in a convection-steam, in an acuthermal bottom pot and in a deep fryer) the nitrite content ranged from 0.21 mg $NO_2 \bullet kg^{-1}$ to 0.26 mg $NO_2 \bullet kg^{-1}$. The calculated nitrate losses ranged from 75 to 80%, which is extremely advantageous for the safety of consumed food. Potato processing in acuthermal pots produced the lowest nitrite losses when compared to the remaining methods. However, the losses were considerable and ranged from 61 to 73%. The differences in nitrate losses obtained for the particular potato varieties subjected to the same processing conditions can be explained by the different capacity of these compounds to migrate outside the tuber. The results indicate that the nitrite losses are greater in the presence of large amounts of water (the "wet" method: in a pot or in a bowl of water in a microwave oven) than in the processes with a limited amount of water (in a convection-steam oven or deep frying).

Conclusion: Nitrates and nitrite contents in potatoes are significantly reduced during culinary processes. The majority of these compounds are removed when tuber peeling and rinsing. The losses of nitrites are greater than the losses of nitrates. It was observed that losses of nitrates and nitrites are significantly higher in peeled potato tubers subjected to thermal processing with direct contact of the product with water. In steam or deep oil, due to the limited access or lack of water which is a good nitrate and nitrite solvent, the losses are significantly lower. In addition, regardless of potato thermal processing technique, the percentage losses of nitrites are greater than those of nitrates. The results obtained indicate that the hygienic quality of potato meals can be determined by potato peeling and by applying a thermal processing method.

References

Chung, S.Y., J.S. Kim, M.K. Hon, J.O. Lee, C.M. Kim and I.S. Song, 2003. Survey of nitrate and nitrite contents of vegetables grown in Korea. Food Additives and Contaminants, 20: 621-628.

Cieslik, E., 1997. Effect of the levels of nitrates and nitrites on the nutritional and sensory quality of potato tubers. Hygiene Nutr. Foodserv. Cater., 1: 225-230.

Commission Regulation (EC) Nr 466/2001 of 8 March setting maximum levels for certain contaminants in foodstuffs. Official J. of the European Communities. EN 2001 L 77/1.

Czarniecka-Skubina E. and B. Golaszewska, 2001. Wplyw procesu kulinarnego na jakosc wybranych warzyw. Zywn. Technol. Jak., 2: 103-116.

Dich, J., R. Jarvinen, P. Knekt and P.L. Penttila, 1996. Dietary intakes of nitrate, nitrite and NDMA in the Finnish Mobile Clinic Health Examination Survey. Food Additives and Contaminants, 13: 541-552.

FAO/WHO, 2002. Expert Committee and Food Additives. Fifty-ninth report of the Joint Techn. Evaluation of certain food additives. Rep. Ser. 913. WHO, Geneva, 2002.

Frydecka-Mazurczyk, A. and K. Zgórska, 2000, Zawartosc azotanów (V) w bulwach ziemniaka w zaleznosci od odmiany, miejsca uprawy i terminu zbioru. Zywn. Technol. Jak., 4: 46-52.

Gaballa, A.A., 2000, Changes in nitrate and nitrite content of some vegetables during processing. Annals Agri. Sci., Cairo., 45: 531-539.

Galler, J., 1997, Nitrates in foodstuffs and their effects on the human organism. Forderungdienst., 45: 53-56.

Golaszewska, B. and S. Zalewski, 2001, Optimalisation of potato quality in culinary process. Pol. J. Food Nutr. Sci., 10/51: 59-63.

Hambridge, T., 2003. Nitrate and nitrite. Intake assessment. INCHEM. WHO Food Additives. Series: 50. http://www. inchem.org/ documents / jecfa/jecmono/v50je07.htm

Hamouz, K., J. Cepl, B. Vokal and J. Lachman, 1999. Influence of locality and way of cultivation on the nitrate and glycoalkaloid content in potato tuber. Rostlinna Vyroba, 45: 495-501.

Hlusek, J., J. Zrust and Juzl, 2000. Nitrate concentration in tubers of early potatoes. Rostlinna Vyroba., 46: 17-21.

Kolbe, H., 1996, Factors influencing the composition of potatoes. Part 4. Nitrate. Kartofelbau, 47: 259-264.

Marin, J., J.A. Zee, P. Levallois, T. Desrosiers, P. Ayotte, G. Poirier and L. Pratte, 1998. Consumption of potatoes and their contribution to dietary nitrate and nitrite intakes. Sci. des Aliments, 18: 163-173.

Markowska, A., A. Kotkowska, W. Furmanek, L. Gackowska, B. Siwek, E. Kacprzak-Strzalkowska and L. Bloñska, 1995. Badania zawartosci azotanów I azotynów w wybranych warzywach surowych oraz poddanych obróbce termicznej. Rocz. PZH., 46: 349-355.

Mazurczyk, W. Lis B., 2003, Zawartosc azotanów I glikoalkaloidów w dojrzalych bulwach ziemniaka jadalnego. Roczn. PZH., 51: 34-37.

Mevissen, L., 1997, Monitoring prevents damage. Occurrence and evaluation of contaminants in plant-based food products. ZFL, Inter. Zeitschr. Lebensmitt. Tech.-Market.,-Verpack.,-Analit., 48: 34-38.

Mikos-Bielak, M., B. Sawicka and B. Rudziñska, 2001, Azotany I azotyny w bulwach wczesnych odmian ziemniaka. Biul. IHAR, 209: 137-147.

Polish Standard Method, 1992. PN-92/A-75112. Fruits, vegetables and derived products. Determination of nitrites and nitrates content.

Rembialkowska, E., H. Kacprzak and J. Sokolowska, 2001. Jakosc zdrowotna warzyw ekologicznych I konwencjonalnych z dawnego woj. kieleckiego. Bromat. Chem. Toksykol., 34: 49-57.

Rutkowska, B., 2001. Azotany I azotyny w ziemniakach z gospodarstw ekologicznych I konwencjonalnych. Roczn. PZH., 52: 231-236

Voronina, L.P., 1997, Nitrate in vegetable produce. Kartofiel I Owoszczi, : 28-29

Zhong, W., Hu c. and M. Wang, 2002. Nitrate and nitrite content in vegetables in China. Food Addit. Contam, 19: 1125-1129.