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ELSEVIER

Correlation between the levels of nitrates and nitrites and the contents of potassium, calcium and magnesium in potato tubers

E. Cieslik* & E. Sikora

Department of Human Nutrition, Agricultural University, 29 Listopada 46, Cracow, Poland

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In tubers of 16 cultivars of consumable potatoes, cultivated in the Experimental Station of Varieties Appraisal at Wegrzce near Cracow in years 1991–1992, the contents of potassium, calcium and magnesium as well as levels of nitrates and nitrites, were determined. Statistical analysis of results showed a significant effect of the year of cultivation and cultivar on the levels of nitrates and nitrites in tubers. A significant correlation between the levels of the studied compounds and the content of potassium in tubers was found; however, in the case of magnesium and calcium the correlation was statistically non-significant.

INTRODUCTION

The contents of nitrates and nitrites in foodstuffs (due to their harmful effects) have been for several years the subject of a number of studies. Particular attention, in this respect, is being given to cultivated plants that play an important part in human and animal nutrition. Nitrates and nitrites, in slight amounts, are natural components of higher plants, and are involved in biochemical and physiological processes. Plants assimilate soil nitrogen, in the form of nitrate; they transform it into ammonium ion through reduction, catalysed by reductases, which differ in the types of metal activators that they require. For example, it was found that, in nitrate, hyponitrate and hydroxylamine reductases, the activator is magnesium, as well as other microelements (Kretowicz, 1986). In those processes, other mineral components present in soil, in particular potassium and calcium, affect assimilation and translocation of nitrates in the plant.

The aim of this study was to trace relationships between the levels of nitrates and nitrites and the contents of potassium, calcium and magnesium in potato tubers.

MATERIALS AND METHODS

The study made use of tubers belonging to 16 cultivars of consumable potatoes, cultivated in the years 1991–1992 in the Experimental Station of Varieties Appraisal at Wegrzce near Cracow under known soil and climatic conditions (Table 1).

Tubers included in the medium trial were washed, dried and comminuted mechanically. In fresh pulp, the content of dry matter, as well as the levels of nitrates and nitrites, were determined using a colorimetric method (Tyszkiewicz, 1986). A dry substance obtained from part of the pulp was 'dry-mineralized' at 450°C and, in the mineralized substance, the levels of magnesium, calcium and potassium were determined using an atomic absorption spectrophotometer (Philips PU 9100).

The results obtained were analysed statistically by the method of two-way analysis of variance. Interrelationships between the studied components were based on correlation coefficients, r, in which significance was verified with the Student's t-test (Krawontka and Bozyk, 1992).

RESULTS AND DISCUSSION

The content of nitrates in the studied potatoes was maintained in the rather wide range of 61–843 mg $NaNO_3$/kg wet mass, averaging 238 mg kg^{-1} (Table 2). The results obtained were consistent with literature data (Grassert *et al.*, 1990; Mica and Becka, 1984). In spite of a not too high mean value, it was found that, in about 31% of studied samples, the amounts of nitrates exceeded a fixed limit of 250 mg kg^{-1} (Decree, 1993). The level of nitrates differed significantly, depending on the year of cultivation. In the study period, the least amounts

*To whom correspondence should be addressed.

Table 1. Soil-climate conditions of grown potatoes

Year	1991	1992
Soil type	Very good wheat complex, brown loessial soil	
Soil pH	7.0	5.0
Soil richness (mg 100 g^{-1})		
P_2O_5	12.1	11.7
K_2O	10.5	10.0
Mg	8.9	10.0
Mean temperature (°C)	16.3	17.4
Total rainfall (mm)	359.7	203.5

Table 2. Content of nitrates (V) in the studied potato cultivars (mg $NaNO_3$ kg^{-1})

Cultivar	Year of cultivation		Mean	SD	Significant differences at p =
	1991	1992			
Ronda	240	61	150	98	Non-significant
Jagna	206	260	233	31	0.01
Jagoda	172	118	145	30	0.01
Mila	342	290	316	29	0.01
Fala	623	86	354	295	Non-significant
Fauna	438	192	320	135	Non-significant
Heban	308	95	202	117	0.01
Ibis	202	139	171	35	0.01
Marta	128	86	107	24	Non-significant
Bzura	110	120	115	11	0.05
Kolia	143	71	107	40	Non-significant
Uran	466	105	231	198	Non-significant
Atol	843	173	508	367	Non-significant
Bryza	548	153	351	217	0.01
Irga	115	216	166	56	0.01
Elba	495	81	288	227	Non-significant
Mean	336	140	238		
SD	208	67		183	
F_o	956.0	162.2			
LSD	19.6	15.6			

of those compounds were found in tubers of cultivars Marta and Kolia (mean = 107 mg kg^{-1}) while the highest levels were ascertained in cultivar Atol (mean = 508 mg kg^{-1}). Statistically significant differences in nitrate levels between cultivars referred only to a half of the studied cultivars, in spite of the fact that earlier studies had shown an effect of genotype on the content of those compounds (Miedzobrodzka *et al.*, 1992).

The observed statistical differences in the contents of nitrates, occurring in the same cultivars at various years of cultivation, might be assigned largely to variable weather conditions since the soil and agrotechnical conditions were in both years of cultivation practically alike (Table 1). Relationships between weather conditions, viz., temperature, insolation, amount of precipitation and the level of nitrates in vegetables have been demonstrated in many studies (Miedzobrodzka *et al.*, 1992)

The potatoes under study were characterized by a relatively high content of nitrites estimated at 2.26 mg $NaNO_2$ kg^{-1} (Table 3), their least amounts being found

Table 3. Content of nitrates (III) in the studied potato cultivars (mg $NaNO_2$ kg^{-1})

Cultivar	Year of cultivation		Mean	SD	Significant differences at p =
	1991	1992			
Ronda	1.63	0.40	1.02	0.68	0.01
Jagna	1.70	1.27	1.49	0.29	0.05
Jagoda	3.43	0.27	1.35	1.75	0.01
Mila	2.53	0.80	1.66	0.98	0.01
Fala	5.73	0.27	2.50	3.00	0.01
Fauna	2.67	0.97	1.83	0.95	0.01
Heban	5.00	1.00	3.00	2.22	0.01
Ibis	4.00	1.43	2.71	1.41	0.01
Marta	2.37	1.17	1.77	0.68	0.01
Bzura	3.03	0.53	1.78	1.38	0.01
Kolia	2.03	1.30	1.77	0.40	0.01
Uran	4.53	1.73	3.13	1.54	0.01
Atol	4.60	1.30	2.95	1.82	0.01
Bryza	4.93	1.60	3.27	1.83	0.01
Irga	3.43	1.50	2.96	1.06	0.01
Elba	3.23	1.87	2.55	0.78	0.01
Mean	3.43	1.09	2.26		
SD	1.24	0.51		1.51	
F_o	66.88	33.13			
LSD	0.444	0.252			

in Ronda cultivars (1.02 mg kg^{-1}) and the highest ones in Bryza cultivars (3.27 mg kg^{-1}). Differences between cultivars proved to be statistically significant.

Likewise, levels of nitrites in particular years of cultivation were found to differ significantly. As for nitrates, potatoes in the first year of study contained more nitrites. Statistical analysis showed a strict correlation between the levels of nitrates and nitrites in the studied tubers ($r = 0.70$) (see Table 7 below).

One of the most important elements occurring in potato tubers is potassium. The potatoes under study contained from 250 to 601 mg potassium 100 g^{-1} wet mass product (Table 4) which is consistent with the ranges of values cited by other authors. The potassium level in tubers depends first of all on the kind and rate of its fertilization, richness of soil, weather and cultivar (Dziekanowski *et al.*, 1992; Ciecko *et al.*, 1994). In this study significant differences in potassium level were found, depending on cultivar and year of cultivation. Similar relationships were shown by Mazurczyk (1988) who found that both factors individually affect this tuber trait; however, the most pronounced effect is seen when they act jointly.

Potassium fulfils a number of important functions in physiological processes in plants, one of them being the role of 'antiion' in transport of nitrate ions NO_3 from the roots to overground portions of plants (Klobus, 1990). In normal biotransformation of nitrates, potassium does not take part directly. However, literature data with respect to the beneficial effect of potassium on photosynthesis and effect of potassium deficiency on proportion changes between fractions of protein and non-protein nitrogen in favour of the latter, are indicative

Table 4. Content of potassium in studied potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivar		Mean	SD	Significant differences at p =
	1991	1992			
Ronda	334	501	415	108	0.05
Jagna	382	454	418	40	0.01
Jagoda	348	512	430	80	0.01
Mila	365	537	401	94	0.01
Fala	370	495	433	68	0.01
Fauna	335	352	343	15	Non-significant
Heban	503	601	552	54	0.01
Ibis	459	556	508	55	0.01
Marta	399	524	462	69	0.01
Bzura	460	496	478	24	Non-significant
Kolia	400	464	432	35	0.01
Uran	420	554	487	73	0.01
Atol	399	489	444	49	0.01
Bryza	371	469	420	54	0.01
Irga	250	480	365	126	0.01
Elba	440	577	508	76	0.01
Mean	390	504	447		
SD	62	56		108	
F_o	17.4	47.0			
LSD	42.5	13.4			

of an indirect action of this element on the above-mentioned biotransformation. In addition studies by Buczek (1980), showed that the presence of potassium ion reduced the effect of inhibiting nitrate reductase (NR) activity through the calcium and magnesium ions in plant tissues under *in vivo* conditions.

The statistical analysis of these findings showed a significant negative correlation between potassium content and levels of nitrates ($r = -0.39$) and nitrites ($r = -0.45$) in tubers, which indicates a beneficial effect of this element on nitrogen transformations in plants. Experiments with potassium fertilization confirm the correlations obtained. Ciecko *et al.* (1994) have shown that potassium deficiency resulted in accumulation of nitrates in potatoes.

Magnesium content in tubers ranged from 12.3 to 25.6 mg 100 g^{-1} wet mass, averaging 17.5 mg 100 g^{-1} (Table 5). The values obtained were close to the lower limit of ranges cited in the literature (Dziekanowski *et al.*, 1992; Mazurczyk, 1988). Statistical analysis showed significant differences in tuber magnesium contents depending on cultivar and year of cultivation. In the second year of studies, over 60% of the studied cultivars were found to contain less magnesium compared to the preceding year.

Magnesium supply is of great importance for the plant since that element is indispensable to a number of enzymatic reactions occurring in the cells. Among others, it enables proper utilization of nitrogen by the plant and its transformation into organic compounds. Despite a direct participation of magnesium in nitrogen biotransformation in the plant, the statistical analysis did not show a significant correlation between its level and the contents of nitrates and nitrites. However, a significant correlation between the levels of magnesium and potassium ($r = 0.31$) was found (see Table 7).

Calcium content in the tubers under study was estimated at 3.36 mg 100 g^{-1} wet mass (Table 6), being in the range (3–17 mg 100 g^{-1}) cited in the literature (Mazurczyk, 1988). Calcium level in the plant is mainly dependent on soil richness, its pH, fertilization and weather conditions (Kêpka, 1976). In this experiment,

Table 5. Content of magnesium in the studied potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivation		Mean	SD	Significant differences at p =
	1991	1992			
Ronda	20.23	21.70	21.0	0.98	0.05
Jagna	14.23	13.30	13.8	0.75	Non-significant
Jagoda	16.70	21.00	18.9	2.36	0.01
Mila	15.33	12.60	14.0	1.59	0.01
Fala	13.67	12.30	13.0	0.76	0.01
Fauna	15.03	13.20	14.1	1.04	0.01
Heban	21.70	17.50	19.6	2.30	0.01
Ibis	19.60	21.10	20.4	0.96	0.05
Marta	18.63	17.40	18.0	0.69	0.01
Bzura	20.33	16.00	18.2	2.39	0.01
Kolia	20.10	17.50	18.8	1.43	0.01
Uran	17.30	15.30	16.3	1.10	0.01
Atol	17.27	20.00	18.6	1.50	0.01
Bryza	17.83	19.10	18.4	0.72	0.01
Irga	10.90	18.90	14.9	4.38	0.01
Elba	25.60	18.30	22.0	2.11	0.01
Mean	17.78	17.20	17.5		
SD	3.49	3.03		3.28	
F_o	101.6	47.0			
LSD	1.019	0.722			

Table 6. Content of calcium in the studied potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivation		Mean	SD	Significant differences at p=
	1991	1992			
Ronda	1.70	1.90	1.80	0.11	0.01
Jagna	1.30	1.50	1.40	0.11	0.01
Jagoda	1.70	1.70	1.70	0.03	Non-significant
Mila	7.80	7.90	7.85	0.05	0.01
Fala	2.20	2.60	2.40	0.22	0.01
Fauna	4.90	4.40	4.65	0.27	0.01
Heban	2.20	2.10	2.15	0.05	0.01
Ibis	1.90	2.40	2.15	0.27	0.01
Marta	1.30	1.40	1.35	0.06	0.01
Bzura	6.00	5.90	5.95	0.06	0.01
Kolia	5.20	5.50	5.35	0.17	0.01
Uran	4.90	5.20	5.05	0.16	0.01
Atol	5.70	5.00	5.35	0.38	0.01
Bryza	2.20	1.90	2.05	0.16	0.01
Irga	1.70	2.10	1.90	0.21	0.01
Elba	2.50	2.80	2.65	0.16	0.01
Mean	3.33	3.39	3.36		
SD	2.00	1.91		1.96	
F_o	46.9	45.8			
LSD	0.48	0.45			

Table 7. Correlation coefficients between determined components of potato tuber

Lp.	Tuber components	1	2	3	4	5
1	Nitrates (V)	1.000	−0.703**	−0.029†	0.183†	−0.386**
2	Nitrates (III)		1.000	0.058†	−0.043†	−0.448**
3	Magnesium			1.000	−0.191†	0.312**
4	Calcium				1.000	0.034†
5	Potassium					1.000

†Statistically non-significant.
*Statistically significant at $p=0.05$.
**Statistically significant at $p=0.01$.

a variability in tuber calcium level was found to be cultivar-dependent.

The presence of calcium in plants is indispensable. Literature data indicate that calcium/magnesium ratio is of significant importance in plants (Buczek *et al.*, 1980). It is thought to have a basic effect on the growth and harvest of plants, particularly of those receiving nitrate ions as a nitrogen source. In this case, a deficiency of both elements is equally as disadvantageous as an excess of magnesium in relation to calcium, since magnesium, due to its antagonistic action, causes a decrease in calcium absorption by plants. However, statistical analysis did not show any relation between those elements.

As in the case of magnesium, no significant correlation was found between calcium content and levels of nitrates and nitrites (Table 7). However, it is common knowledge that the content of elements in plants is correlated with their levels in the soil, and in turn pH depends on how rich those elements are in the soil, which markedly affects the intake and accumulation of nitrates in plant. Thus, they exert an indirect effect on the levels of nitrates and nitrites, playing a significant role in transformation processes of nitrogen substances in plants.

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