International Journal of Horticultural Science 2006, 12 (1): 21–25
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Investigation of nitrate accumulation in green pepper

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Summary Pepper, despite being among the vegetables consumed in largest quantities, does not play an important role as a nitrate source due to the low nitrate accumulation capacity of the cultivars grown in Hungary. In the classification of the average nitrate levels or that of the detected hazardous levels it can be sorted into the very 'favorable' class not exceeding 200 and 500 mg/kg respectively. The different elements of the production technology, this way the N supply, do not influence significantly the amount of nitrate accumulated within pepper fruits.

Key words: *pepper, nitrate content, nutrient supply*

Introduction

Vegetables and fruits are playing an ever greater role in modern nutrition, unfortunately, in connection with their consumption, some unfavorable factors must also be taken into consideration, such as pesticide residues, heavy mineral contamination and nitrate-nitrite content which has been widely debated and studied for the last two decades.

Pepper plays a very important nutritional role in Hungary, according to *Hodossi* et al. (2004) annual consumption in the country is 10 kg/capita, the majority of which is greenhouse grown as a result of the spread of the technology of long culture greenhouse pepper production (*Zatykó*, 1985; *Slezák*, 2004). Therefore, there are good reasons for investigating pepper fruit composition also in this aspect. A number of research results and instances of practical experience confirmed our hypothesis which tried to find a correlation between the amount of nitrogen accumulated in the fruits and fertilization, as well as soil nitrogen supply (*Terbe*, 1993).

Data from the literature are in agreement that the majority of the nitrate in our body enters the human organism through drinking water and the consumption of vegetables. According to *Scharpf-Wehrmann* (1991) 70% of the nitrate is of plant origin, mostly vegetables, 20% comes from drinking water and 6% from meats. *Selenka* (1980), *Fritz* (1983); *Schlatter* (1985) and *Titz* (1989) publish identical data to those reported by *Biedermann* et al. (1980), which authors attribute the origin of the nitrate content entering the human body in 70% to vegetables, in 20% to drinking water and approximately in 10% to the consumption of milk, fruits, cereals and meats. Somewhat different is the opinion of *Virágh* (2004) who ascribes the primary reason of methemoglobinemia to poor quality drinking water. From the references cited it can be concluded that the nitrate load of the human body is closely correlated with vegetable consumption, with the amount of the vegetable consumed and its species composition.

According to FAO and JECFA (Joint FAO/WHO Expert Committee on Food Additives) the lower limit of nitrate level that is already harmful to human body is 3.65 mg per 1 kg body weight, while the upper limit is 5 mg/kg which is equivalent to an intake of 255.5 mg per day for a 70 kg adult. (EPA, the US Environmental Protection Agency allows a 7 mg/kg concentration). The admissible nitrite concentration for adults is 0.139 which is equivalent to 9.73 mg per day nitrate, corrected to 70 kg body weight. The admissible limit for artificial baby milk and infant milk and for diabetic food is set at 250 mg/kg nitrate in the standard. The literature is far from being unanimous on critical nitrate and nitrite doses, there are opinions which go to the extreme to saying that nitrate has absolutely no toxic effect on human body (*Möhler*, 1975; *Wedler*, 1984). The National Health and Nutrition Institute sets the critical nitrite level at 0.18–2–5 mg/kg – calculated in $NaNO_3$.

Nutrient accumulation, consequently the accumulation of nitrogen, does not show a uniform pattern in plants thus the difference from plant organ to plant organ can be considerable. The highest nitrate levels can be detected in transport tissues, particularly where the proportion of the xylem is relatively high as compared to the other transport tissues and where the vacuoles are fully developed. It means that the accumulation of nitrate in vegetable fruits basically depends on which part of the plant is to be consumed in botanical sense (*Koter*, 1967; *Maynard-Baker*, 1971; *Peck* et al., 1971; *Kohert*, 1974; *Lorenz*, 1978; *Matula*, 1983; *Debreczeni*, 1986; *Titz*, 1989; *Veres* et al., 2003). The greatest accumulation is in the stem, in leaf stalks and in elderly leaves, while the lowest in the generative organs where the fruits of onion and potato represent a transition in this sense.

Substantially the above mentioned conclusion is reflected in the classifications that distinguish dangerous species from less dangerous ones based on the nitrate levels in the fruits of the respective vegetables. The German classification is generally accepted and used internationally according to which pepper is indicated in the group without any tendency to accumulate nitrate (*Table 1*), and also the national experiments seem to bear out this classification. *Gyalmos* (2004) puts pepper together with tomato and patisson in the vegetable group with the lowest nitrate level, with less than 200 mg. Contrary is the opinion of *Matula* (1983), according to which the family Solanaceae comprises nitrate accumulating species, and similarly *Koter* (1967) lists the *Solaneceae* plants together with the families *Urticaceae*, *Poaceae*, *Boraginaceae* and *Chenopodiaceae* as high nitrate level plants, at the same time the authors do not mention pepper among them.

The classification by 'dangerousness' is also common, which groups the vegetables not according to the average but to the maximum values found (*Table 2*). Also according to this rating pepper belongs to the very favorable group not exceeding 500 mg/kg.

Table 1. Classification of vegetables according to nitrate level based on average values

<200 mg/kg	200–500 mg/kg	500–1000 mg/kg	1000–2500 mg/kg	2500< mg/kg
pea tomato asparagus brussels sprout pepper leaf chicory melon cucumber	eggplant onion cauliflower string bean red cabbage black root cabbage pumpkin savoy cabbage	leek kohlrabi squash broccoli kale garden cress	parsley endive caraway celeriac celery cabbage spinach red beet radish rhubarb blanched celery	lettuce winter radish corn salad mangold purslane

(Bundesforschungsanstalt für Ernährung)

Table 2 Classification of vegetables according to nitrate content based on maximum values found (Bundesforschungsanstalt für Ernährung)

<200 mg/kg	200–500 mg/kg	500–1000 mg/kg	1000–2500 mg/kg	2500–3000 mg/kg	3000< mg/kg
pea tomato	eggplant pepper leaf chicory black root	cucumber melon brussels sprout asparagus squash potato	string bean cauliflower broccoli white cabbage savoy cabbage kohlrabi pumpkin onion parsley	winter radish corn salad mangold purslane	celery cabbage caraway corn salad leek winter radish blanched celery rhubarb collard endive celeriac red beet spinach mangold purslane radish cabbage lettuce

(Bundesforschungsanstalt für Ernährung)

In terms of nitrate content pepper is regarded in the Netherlands and in Switzerland as a 'harmless' plant therefore is not listed among the critical plants. According to measurements carried out in Germany, in the case of pepper the highest value is 220mg/kg, the average reference value is 140 mg/kg, which is basically identical to that of tomato (130 mg/kg) and that of cucumber (150 mg/kg).

Public opinion is dominated by the conviction that excessive nitrate content in fruit is the consequence of over fertilization. The relative literature highlights several other reasons in extra early production, first and foremost unfavorable light conditions as the most critical factor (*Terbe*, 1993).

Miyazaki et al. (1968), *Pimpini* et al. (1971), *Eerola* et al. (1974), *Slangen-Bremier* (1983), *Venter* (1983), *Wendt* (1983), *Handel* (1984), *Kübler* et al. (1984), *Handel* (1986), *Scharpf-Weiler* (1988), *Bíró* (1993) and *Némethy* (2001) found a correlation between the doses of nitrogen fertilization and the nitrate content of the edible parts of spinach, leek, lettuce, cauliflower, kohlrabi, celery, red beet, radish and carrot. There are fewer authors who have managed to demonstrate a similar relationship between soil nitrogen concentration and the nitrogen content accumulated in the edible part (kohlrabi, celery, lettuce) (*Pieters-Van der Boon*, 1983; *Wendt*, 1983; *Titz*, 1989).

Material and method

In order to investigate the degree of nitrate accumulation in the fruit of pepper, samples were collected at the Plant Protection and Agrochemical Station of the county Csongrád and at the Plant and Soil Protection Service of the county Csongrád, its legal successor, in Hódmezővásárhely, at the Experimental Farm of the University of Horticulture and Food Industry, the legal predecessor of the Experimental and Educational Farm of the Corvinus University of Budapest, as well as at 7 greenhouse vegetable growers.

The growers included in the survey were farms that were generally at a high level of production, situated mostly in the counties of Csongrád and Pest, with greenhouse and outdoor production. The green pepper cultivars tested were divided into two groups: white fruited types and Hungarian hot types. At the same time of the collection of the fruit samples soil samples were also taken from which the amount of readily accessible nitrogen was determined by using the method of *Göhler*, with the nitrite + ammonium nitrogen value measured in 1:5 aqueous extract and based on the evaluation of the N minimum.

Nitrate content of vegetables shows considerable singular variance which is greater than that of any other chemical parameter, even under identical growing site conditions. The level of variance changes with plant part, generally the variance measured in the pepper fruit is smaller than that in the leaves. Considering this fact, each bulk sample was produced by processing 15–20 fruits (partial samples). It is known that nitrate levels are influenced by the weather and the alternation of day part, therefore samples were taken on each occasion almost at the same time at noon. We used cooler bags to carry the samples for laboratory processing.

Prior to chopping, the samples were washed with tap water then the stalk and the core were removed and a sample of 60 g (bulk sample) was produced from the parts fit for consumption. The sample was added 60 cm^3 distilled water and then chopped with a kitchen blender.

Nitrate was extracted from the pulp with potassium chloride. 10 g of sample was measured out, which was then added 100 ml 1% potassium chloride and kept boiling for 15 minutes. Evaporated water was replaced and after having cooled down the sample was made up to 100 ml and filtered. Determination of nitrate was carried out with a continuous chemical analyzer based on color reaction.

Soil samples were collected at the same time as the fruit samples and each bulk sample produced from 10–15 point samples from the 15–25 cm soil layer. Assessments were made of the water-soluble soil nitrogen content based on a 1:5 extraction, as well as for the NO_3+NO_2 content according to *Göhler* and for the N min value.

Table 3. Nitrate concentrations in the fruits from the growers

Variety type	Growing facility	Number of samples	NO_3 mg/kg		
			Minimum	Maximum	Average
Varieties with white fruit (for stuffing)	Glasshouse	23	24	209	78
	Plastic tunnel	63	21	276	104
	Field	19	128	233	167
Hungarian hot types	Glasshouse	39	76	260	81
	Plastic tunnel	6	57	270	119

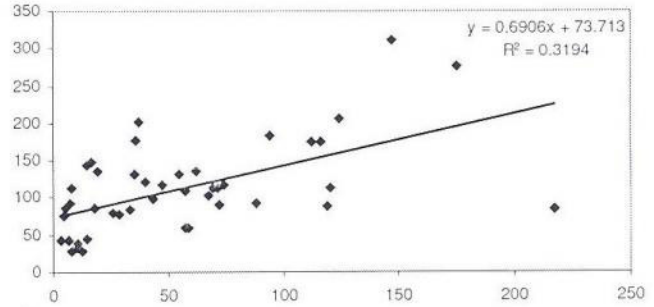

Fig. 1. Relationship of fruit NO_3 concentrations of white fruited cultivars and soil N-min values

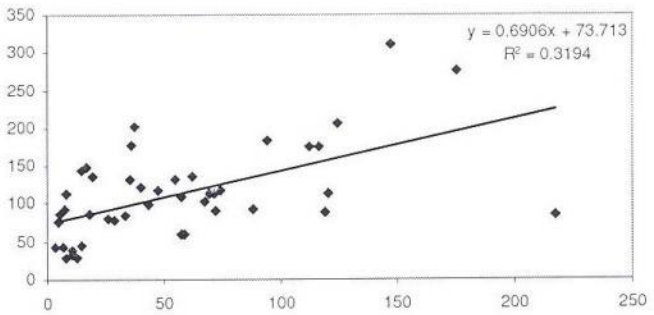

Fig. 2. Relationship of fruit NO_3 concentrations of white fruited cultivars and soil N values according to the Göhler method

Results

150 pepper samples from greenhouse, plastic tunnel and outdoor growers were analyzed for nitrate content and assessment was made of the soil nitrogen content according to the method of *Göhler* and that of N-min, as well as of the N value detected from the aqueous solution. The samples were collected in the period between March and July, and soil samples were collected together with the fruit samples.

Nitrate concentrations of the fruit samples collected, except for a few extraordinarily high values, were inferior to the levels regarded as critical for vegetables, thus the investigations seemed to confirm the researchers putting pepper in the 'not dangerous' category (*Gyalmos*, 2004). Detected maximum values did not exceed the 300 mg/kg limit and the averages remained below the concentration set by FAO and Bundesforschungsanstalt für Ernährung (*Table 3*).

No relationship between soil nitrogen supply and fruit nitrogen concentration was observed either with the white or with the pointed varieties relative to the two N analysis methods (stuffing type pepper N min method correlation factor: 0.501666, stuffing type pepper *Göhler* method correlation factor: 0.565191, see *Tables 1–2*).

Similarly to what was said above, no correlation was found between water soluble soil (1:5) nitrogen content, commonly utilized by crop advisory systems, and fruit nitrate concentrations (*Table 4*). (The 10–12 mg/100g supply level is to be considered as high, while the 7–8/100 mg as medium.) In contrast, far more spectacular was the decrease in the nitrate content in parallel to the improvement of light conditions during the growing season. Some extremely high values did occur in the measurements (452 and 390/100mg) which were probably attributable to intensive foliar fertilization.

During the investigations conducted over several years no significant relationship was found between fruit nitrogen concentrations and soil nitrogen status, and the F test carried out did not reveal any significant difference. In several

Table 4. Nitrate concentrations in pepper fruits and water soluble nitrogen contents of associated soils

Sample number	Water soluble soil nitrogen concentration (mg/100 g)			Fruit NO_3 concentration mg/1000 g		
	IV. 1.	IV. 23.	VI. 23.	IV. 1.	IV. 23.	VI. 23.
1	10	12	12	390	239	246
2	11	11	14	115	87	–
3	12	8	–	452	328	134
4	–	11	11	–	–	216
5	8	15	13	239	129	118
6	7	8	12	106	84	35
7	7	7	–	230	220	–

instances the regression coefficient showed a very loose relationship, the variance of the results obtained is well demonstrated in *Figures 1–2*. According to the d factor soil nitrogen content determines the instantaneous nitrogen concentration of the fruit only not more than in 10–20%.

It is common in several countries (mainly the exporters) to distinguish winter and summer limits when characterizing crop quality, as both day length and light intensity have significant influence on nitrate concentration. With a few varieties for greenhouse production the samples from the growers were tested in this aspect as well, and later the fruits coming from comparative variety trials conducted at the Experimental and Educational Farm of the Corvinus University of Budapest at Soroksár and at the company Árpád Agrár Rt. in Szentes (*Tables 3–4*).

Nitrate content showed a decrease over the growing period, but in a degree that varied from variety to variety. The considerable difference between the first and the second test can be attributed to the unfavorable, cloudy weather dominating the period of the first pickings (*Table 4*).

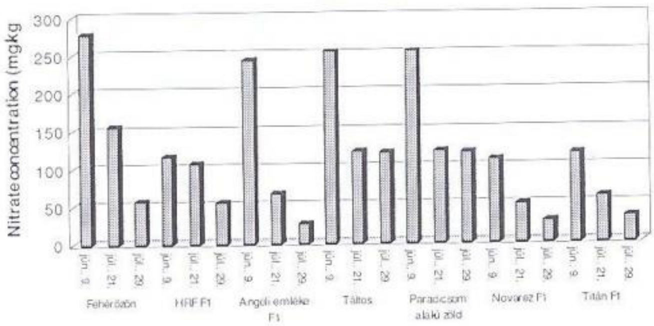

Fig. 3. Variation of the nitrate concentration of the pepper varieties during the growing season

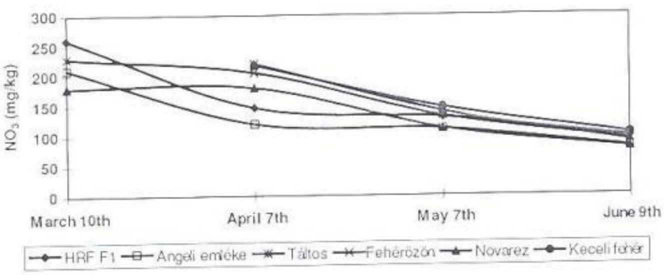

Figure 4. Changes in nitrate concentration in response to light conditions (day length) and varietya

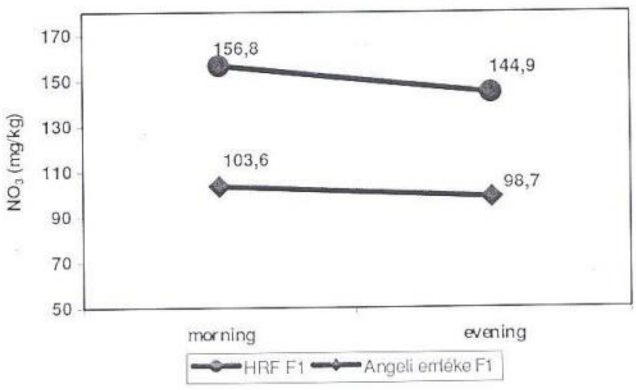

Fig. 5. Daily fluctuations of nitrate content in pepper fruit

With the lengthening of the day, i.e. with the improvement of light conditions, a significant diminishment is observable in the nitrate accumulation of fruits, even in the case of plants such as pepper not characteristically nitrate accumulating. With certain varieties the decrease was greater than 50%. The degree of the diminishment varied from variety to variety, in general it can be stated that the white fruited variety group showed higher values than the Hungarian hot variety type.

In order to reduce the nitrate concentration in the crop, some vegetables are recommended to be harvested in the evening rather than in the morning (e.g. spinach, lettuce). After having studied the question also in this context, it can be said that there was some minor difference (decrease) with pepper as well between morning and evening pickings under sunny weather conditions, but no statistically distinguishable difference could be detected (*Figure 5*). Probably, with those vegetables where the product in a commercial sense, i.e. the edible part is the leaf (lettuce) or the leafstalk (rhubarb) or stem (onion, leek) a higher difference is detectable in terms of nitrate concentration between the parts of the day compared to those vegetables where the product in a biological sense (fruit) is identical with the commercial product.

Conclusions

From the results of the trials and based on the analysis of the fruit samples collected from the growers it can be concluded that green peppers do not belong to nitrate accumulating vegetables. Not counting some occasional extremes, even in winter months poor in light the fruit nitrate content does not exceed the level of 200–300 mg/kg, which is to be regarded as a low category in classification tables known. No relationship was detectable between soil N content according to Göhler or N minimum or water soluble N value and fruit nitrate content. No significant difference exists in terms of variety or variety type, nonetheless with the white fruited stuffing varieties somewhat higher fruit NO_3 values are observable. In parallel to improving light conditions fruit nitrogen contents diminish significantly though not reaching the critical level even in poorly lit winter months. Fruit nitrate concentrations are somewhat higher in the morning hours than in the evening, however the differences detected do not constitute sufficient grounds for the application of evening pickings in the case of pepper.

Conclusions

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