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Nitrate accumulation in potato affected by nitrogen fertilizer

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ABSTRACT: Potatoes are not only an important source of energy, but also contain a number of micronutrients, such as vitamin C and some forms of vitamin B, potassium, magnesium, iron, and zinc. Depending on dietary habits, potatoes can be the main source of nitrate intake. Namely, vegetables account for 97% of our nitrate intake, of which 32% originates from potato consumption and 29% from lettuce consumption. Nitrogen is an essential element required for successful plant growth. Although inorganic nitrogen compounds account for less than 5% of the total nitrogen in soil they are the main form of the element absorbed by most plants. Inorganic and organic fertilizers are applied to maintain the nutritional condition of different cropping systems. Nitrate per se is relatively non-toxic, however by the action of natural bacterial flora in the buccal cavity approx. 4-7% of the nitrate intake is reduced to more toxic nitrite). In the acidic environment of the stomach, nitrite is converted to nitric acid and other N-nitroso compounds, which may react with secondary amines to form cancerogenic nitrosamines.

***Keywords*:** Light intensity, Nutritional factors.

INTRODUCTION

Potato is an important and popular food in the European Union EU as it is by consuming quantities in the second place, behind wheat. The highest consumption per person per year is in Latvia - 178 kg, while in Poland it is 118 kg and in Greece 103 kg. In Slovenia, the consumption of 84 kg of potatoes per person per year is above the European average of 73 kg (Eurostat, 2011). Potatoes are not only an important source of energy, but also contain a number of micronutrients, such as vitamin C and some forms of vitamin B, potassium, magnesium, iron, and zinc (Weichselbaum, 2010). Depending on dietary habits, potatoes can be the main source of nitrate intake. Namely, vegetables account for 97% of our nitrate intake, of which 32% originates from potato consumption and 29% from lettuce consumption (Santamaria, 2006; Thomson, Nokes, & Cressey, 2007).This article is review article and the main is nitrate accumulation in potato affected by nitrogen fertilizer.

Nitrogen

Nitrogen is an essential element required for successful plant growth. Although inorganic nitrogen compounds account for less than 5% of the total nitrogen in soil they are the main form of the element absorbed by most plants. Inorganic and organic fertilizers are applied to maintain the nutritional condition of different cropping systems (Ginting et al., 2003). For an organic agricultural system, continuous application of manure increases the nitrogen (N), phosphorus (P), potassium (K), calcium, and magnesium content in soil Once organic fertilizers are applied to soils and mineralization begins, inorganic nitrogen is released and absorbed by plants. However, the rate of mineralization is controlled by several factors, including agricultural management, microorganism, soil properties, temperature, and water content as well as the type of organic fertilizer. Once nitrogen fertilizers are applied to agricultural systems, the fertilizers are absorbed directly by plants or converted into various other forms through the oxidation process (Watts et al., 2010). Excess nitrogen is lost in ionic or gaseous form through leaching, volatilization, and denitrification. If nitrate is not absorbed by plant roots, it is carried away by runoff or leaches into the soil along with water (Tamme et al., 2009). The phytoavailability of the nitrogen pool increases when excess nitrogen is applied, and this increase intensifies the potential threat to the surrounding environment. There are close relationships between the excessive application of nitrogen fertilizers and environmental problems such as eutrophication, the greenhouse effect, and acid rain (Sharifi *et al*., 2011).

The factors leading to the difference of nitrate contents

The factors responsible for nitrate accumulation in plants are mainly nutritional, environmental and physiological. Nitrogen fertilization and light intensity have been identified as the major factors that influence the nitrate content in vegetables (Cantliffe, 1973). The factors leading to the difference of nitrate contents in different vegetables are complex and a number of studies on the mechanism of nitrate accumulation have been done, mainly on the nitrate uptake rate, nitrate reductase activity, and growth rate, which are closely related to carbon metabolism. Besides the genetic factor, growth conditions also play a decisive role in the nitrate accumulation of plants: nitrogen fertilizers, variety and crop protection strategies, soil moisture, light intensity and temperature (Hmelak Gorenjak, & Cencič, 2013). However, the fundamental factor of nitrate content in vegetables should be the imbalance between nitrate uptake and reduction (Du, Zhang, & Lin, 2007).

Light intensity

Diurnal changes in light intensity lead to a diurnal pattern of nitrate accumulation in plants. Many nutrients, such as chloride, calcium, potassium, sulfate and phosphorus, are involved in the nitrate accumulation process in plants. The nitrate content varies in various parts of a plant (Anjana et al., 2006) and with the physiological age of the plant. A reduction in nitrate content can add value to vegetable products already very popular for their nutritional and therapeutic properties (Santamaria, 2006).

Nitrate

Nitrate per se is relatively non-toxic (Speijers, 1996), however by the action of natural bacterial flora in the buccal cavity approx. 4-7% of the nitrate intake is reduced to more toxic nitrite). In the acidic environment of the stomach, nitrite is converted to nitric acid and other N-nitroso compounds, which may react with secondary amines to form cancerogenic nitrosamines (Walker, 1990). A well-known adverse effect of nitrate to human organism is the binding of nitrite to haemoglobin, resulting in formation of methaemoglobin (Hmelak & Cencič, 2013).

Nutritional factors

Nazaryuk et al. (2002) have studied the role of agricultural chemicals in regulating the nitrate accumulation in plants and shown that the process of nitrate accumulation depends on three major groups of factor: application of mineral fertilizers, treatment with physiologically active substances and sorbents, and the natural and anthropogenic changes in the soil environment. With respect to their impact on nitrate accumulation, these factors may be arranged in the following descending order: fertilizers > physiologically active substances > soil. To explore the possibility of controlling the nitrate accumulation in plant tissues, it is important to estimate the effect of an exogenous nitrogen supply on the degree of utilization of nitrogen from soil as well as fertilizers (Nazaryuk et al., 2002). Nitrogen fertilization facilitates accumulation of nitrate in plant tissues as a result of an excess of nitrogen uptake over its reduction. When taken up in excess of immediate requirement, it is stored as free nitrate in the vacuole and can be remobilized subsequently when nitrogen supply is insufficient to meet the demand (van der Leij et al., 1998). Nitrate accumulation in vegetables often depends on the amount and kind of nutrients present in the soil and is closely related to the time of application, and the amount and composition of the fertilizers applied (Zhou et al., 2000). An adequate fertilization program may ensure sufficient plant growth without any risk of plant nitrate levels going too high (Vieira et al., 1998). Plants accumulate more nitrate as the nitrogen fertilization level increases (Chen et al., 2004), whereas limiting the nitrogen availability reduces nitrate content significantly (McCall and Willumsen, 1999).

Responses of potato to low or high supply of N

Such responses to low or high supply of N arise from effects of N on rate and duration of appearance of leaves and branches on the potato plant and depend on the active life span of individual leaves. Many processes determining leaf production are not sensitive to N over a wide span of (suboptimal) N supply. These include the rate of leaf appearance, the timing of appearance of basal or apical lateral branches and the duration of leaf expansion. Specific leaf area is not systematically altered by N over a large range of supply. For spaced plants, the active life span of leaves tends to be longer at high rates of N supply than at lower rates (Biemond and Vos 1992). Full-grown areas of individual leaf ranks are extremely sensitive to N supply because leaf expansion rate is sensitive, but the duration of leaf expansion is not. In conclusion, the prime factors responsible for divergent patterns are the number of branches per plant and individual leaf size Vos and Biemond (1992). For a large range of N supply, the leaf/stem ratio (dry weight) remains constant and so do the harvest indices for dry matter and nitrogen of fully matured crops. However, when high-N crops are prematurely harvested and compared to low-N crops, the harvest indices are higher for the latter than for the former. There is some delay in the onset tuber bulking with large rates of N supply. At high rates of N supply, there is some shift in relative N distribution in the plant in favour of the proportion N in stem material (Wu et al. 2007). The nitrogen concentration in leaves and its change over the life span of the leaf area are not very sensitive to N nutrition. Since photosynthetic capacity is associated with leaf N concentration, it follows that photosynthetic capacity of leaves is only weakly affected by N nutrition (Marshall and Vos 1991).

Nitrate Contaminated Groundwater and Nitrate Levels in Potatoes

The influence of nitrate contaminated groundwater on nitrate levels in potatoes can only be indirect – through irrigation (Gorenjak et al., 2014). On DP plain, potatoes are not irrigated with nitrate polluted groundwater, thus, due to the shallow roots of the potato, this will not affect nitrate levels. Rather than determining the effect of nitrate polluted groundwater on nitrate levels in potatoes, it is more reasonable to explore the long-term impact of introducing sustainable agriculture, which aims at protecting the groundwater, on the quality of potatoes, in the area of Siget and Rače, where the groundwater has the lowest nitrate concentration on DP plain (from 25 to 50 mg/L), the number of samples exceeding the MRL (200 mg/kg) of nitrate content was the highest (4 samples) (Gorenjak et al., 2014). The average nitrate content in samples of potato was 197 mg/kg (ranging from 41 to 429 mg/kg). Potato samples collected from areas within the DP plain in which groundwater measurements indicate heavy nitrate pollution year after year (from 50 to 75 mg/L) had average nitrate levels of 177 mg/kg (ranging from 49 to 408 mg/kg) (Gorenjak et al., 2014). MRL of nitrate concentration was exceeded in 2 samples. The nitrate content of potatoes grown in Brunšvik and Lancova vas, where groundwater measurements consistently exceed the MCL (even above 75 mg/L), is in fact the lowest - ranging from 57 to 174 mg/kg. The area of Lancova vas is defined as water protected area. Low levels of nitrates in potato can be explained by strict adherence to the rules set by the water protection area law(Gorenjak et al., 2014). Potatoes collected in Brunšvik were grown outside the water protected area, but on the farm with consistent integrated production systems. The use of nitrogen fertilizers and the intensity of the light are the major factors that influence nitrate content in vegetables (Santamaria, 2006), therefore strict following of GAP, by lowering the use of nitrogen fertilizers, results in lower nitrate accumulation in vegetables. Introduction of water protected areas in order to protect the groundwater reflects in better quality of potato, regarding nitrate content, as well.

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