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Original Article

Influence of harvest date on nitrate contents of three potato varieties for off-season production

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ABSTRACT

The influence of potato variety and harvest date was investigated on tuber nitrate content for off-season production in three varieties: Arinda (mid-early), Spunta (mid-late) and Mondial (late). Samples of tubers were harvested at 90, 105 and 120 days after planting in winter–spring crop and at 80, 95 and 110 days after planting in summer–autumn crop. Tuber nitrate content was determined by ion selective electrode (ISE) method. Investigated varieties differed in nitrate content. In both off-season crops, the highest quantities of nitrate were contained in the late Mondial, with respect to the middle early Arinda variety and Spunta. After a delay of the harvest date, nitrate contents in the investigated tuber samples significantly decreased in winter–spring crop, whereas they increased in summer–autumn crop in the three varieties, but to the greatest extent in the case of late Mondial variety. Regardless of variety and harvest time, the content of nitrate in tubers was within the guidelines proposed by some European countries.

1. Introduction

Nitrates are naturally occurring compounds in vegetables, since their presence in the plants is connected with the nitrogen transformations to amino acids and proteins. Nitrate per se is relatively non-toxic (Speijers, 1996), but approximately 5% of all ingested nitrate is converted in saliva and in the gastrointestinal tract to the more toxic nitrite (Pannala et al., 2003), which is associated with gastric cancer and methaemoglobinaemia in infants (Knobeloch et al., 2000; Maynard et al., 1976; Mensinga et al., 2003).

The European Communities Scientific Committee for Food (SCF) set the Acceptable Daily Intake (ADI) for NO_3^- at 3.65 mg kg^{-1} body weight day^{-1} (Commission of the European Communities Scientific Committee for Food, 1992). Potato (*Solanum tuberosum*) is classified among vegetables with low nitrate content (Corré and Breimer, 1979; Schuddeboom, 1993). However, because of the large amounts consumed, it can contribute greatly to the daily intake of nitrate in the diet (Santamaria et al., 1999; Santamaria, 2006). This is the reason for the fact that increasing attention is being paid to potato nitrate content (Gravoueille et al., 1992; Ysart et al., 1999). To date, no official limits for nitrate content of potato have been set in the European Union, although several countries have put forward the proposal of guidelines. In Germany, for instance, only tubers with less than 200 mg NO_3 kg^{-1} fresh weight (Santamaria, 2006) are accepted; and in Poland there is a maximum limit of 183 mg NO_3 kg^{-1} fresh weight (Cieslik and Sikora, 1998). The amount of nitrates in tubers has been shown to vary with the cultivar, maturity of the tubers and their size, type and amount of nitrogen fertiliser, weather, site and storage conditions (Augustin et al., 1977; Bèlanger et al., 2002; Gislason et al., 1984; Lachman et al., 2003; Rogozinska et al., 2005; Serio et al., 2004).

Contents of nitrates in potato tubers of most edible varieties oscillate between 40 and 500 mg kg^{-1} of fresh matter, though on average do not exceed 300 mg kg^{-1} of fresh matter (Lisinska and Leszczynski, 1989), confirming that consumption of potato, particularly of potato subjected to the peeling process, does not endanger human health (Peksa et al., 2006; Rytel et al., 2005).

In several countries of Mediterranean Basin, such as North African countries, Cyprus, Turkey and in southern Italy, potatoes are not grown in the usual cycle (spring–summer) due to high temperatures and considerable demand for water, but are mainly grown in off-season cycles (mainly winter–spring cycle and summer–autumn) for early potato production. Early potatoes are defined as "potatoes harvested before they are completely mature, marketed immediately after harvesting and whose skin can be easily removed without peeling" (UNECE of Geneva, FFV-30/2001).

Immaturity in potato tubers has been connected with high nitrate levels, but the relationship between nitrate concentration

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and maturity is not clear, and is likely to differ between genotypes (Kolbe and Stephan-Beckman, 1997; Lachman et al., 2003; Serio et al., 2002). Moreover, in off-season potato production, when tubers are harvested very early, low dry matter content creates a soggy texture and decreases potato quality (Mustonen, 2004).

There is still an increasing demand for early tubers, harvested at different stages of their maturity and consumed as cooked potatoes. This prompts a need to determine the amounts of nitrates in early potato tubers from both the two off-season crops, as well as to estimate the risk of their consumption. The purpose of this investigation was to define the influence of potato variety and harvest date on tuber nitrate content, unit weight and dry matter content of early potatoes.

2. Materials and methods

2.1. Experimental design, plant material and crop management

Field trials were carried out during 2005 and 2006 in Sicily along the coastal plain area south of Siracusa (37°03′N, 15°18′E, 15 m a.s.l.), which is a typical area for off-season potato cultivation in southern Italy. Two off-season crops (winter–spring and summer–autumn) were undertaken in a randomized split-plot design with three replications, including three varieties (Arinda, Spunta and Mondial) as main plots and three harvest times as subplots. The three potato varieties are among the most cultivated in off-season crops in the Mediterranean region, and are considered, respectively, mid-early, mid-late and late.

The three tuber harvests in both years were realized at about 90, 105 and 120 days after planting (dap) in winter–spring crop and at about 80, 95 and 110 days after planting (dap) in summer–autumn crop. Subplot size was 3.0 m × 3.0 m with 40 plants spaced 0.3 m apart, in rows separated from one another by 0.75 m (equivalent to a planting density of 4.44 plants m^{-2}). In winter–spring crop, sowing was carried out on 10 and 15 January in 2005 and 2006, respectively, while in summer–autumn crop on 16 and 26 August in the 2 years, respectively.

In both years for winter–spring crop, imported virus-free seed-tubers were utilized; in summer–autumn, tubers produced locally in the previous spring and stored seed potatoes were used. Whole tubers were planted manually. All plants emerged 30 days after planting from both planting dates. Crops were supplied with 100% ETM. ETM (net of rain) was calculated using the following formula:

$$\mathrm{ETM} = \sum_{0}^{n} E\,Kc\,K\,p$$

where n is the number of days since the last watering; E the daily evaporation from an unscreened class A Pan situated about 40 m from the crop; Kc the crop coefficient which varied from 0.45–1.15 in relation to the phase of the crop's biological cycle; and Kp the correction coefficient in relation to evaporation, which is 0.8 in the Mediterranean area (Doorembos and Kassam, 1979). Drip irrigation was applied when the accumulated daily evaporation reached 40 mm.

Ammonium monophosphate (200 kg ha^{-1}) and chlorpyrifos (30 kg ha^{-1}) were applied before planting, and 200 kg ha^{-1} of ammonium nitrate after plant emergence. Standard crop management was applied, involving post-emergence weeding with linuron and pest control when needed.

2.2. Sample collection

For each harvest time the harvest area consisted of 20 plants from the centre plot. Tubers were selected by diameter classes (<35 mm, 35–70 mm and >70 mm), counted and weighed. A sample of tubers per plot of diameter class 35–70 mm and without any kind of anomaly was selected.

2.3. Sample preparation

Selected tubers were washed in distilled water to remove any soil, blotted dry, and sliced into strips 10 mm wide but with differing lengths. The dry matter of fresh potato tubers was determined after being dried at 65 °C and until constant weight was achieved (AOAC, 2005). Then strips were pressed through a 1 mm stainless steel sieve. The dry material obtained was used for defining the nitrate content.

2.4. Nitrate analysis

Nitrate was extracted from a 1 g sample of dried ground tuber, and analysed using ion selective electrode (ISE) method, and a pH-meter (pH 2100 of Eutech Instruments) according to Wilhelm et al. (2000). 1 g of dried ground tuber was shaken with 200 mL of 0.04 M $(NH_4)_2SO_4$ for 30 min. Reference and NO_3 selective electrodes were placed directly into the agitating extraction media and electrometer readings observed. Readings were recorded after sequential additions of 1 mL aliquots of NO_3 interference suppressor. A total of 108 samples were analysed; all analyses were carried out twice.

To express the NO_3 content on the fresh matter, the value was converted considering the dry matter content.

2.5. Statistical analysis

All data were submitted to Bartlett test for the homogeneity of variance and then analysed using ANOVA (Snedecor and Cochran, 1989). Given that the year did not have a significant effect, a separate ANOVA regardless of years was conducted for each crop cycle, as a factorial combination of variety × harvest date. Means were compared by *LSD* test, provided the *F* test was significant. Polynomial effects up to second degree were made where appropriate to define the response of trend (linear or quadratic) between harvest time and characteristics of tubers. Correlation analyses were made between nitrate content, mean tuber weight and dry matter content. CoStat Version 6.003 (CoHort Software) was utilized.

3. Results and discussion

3.1. Winter–spring crop

Throughout the winter–spring crop, the minimum mean monthly temperatures, on average of the 2 years, gradually increased from 7.5 °C (January) to 14.1 °C (May); the maximum mean monthly temperatures increased in the same period from 15.3 °C to 24.7 °C, the mean monthly day-length increased from 10.6 to 15.0 h and photosynthetically active radiation (PAR) increased from about 4.5 to 13.5 MJ m^{-2} day^{-1}.

On average of harvest date and variety, tuber nitrate content was 130 mg kg^{-1} f.m. At the first harvest (90 dap) tuber nitrate content was higher in Mondial (208.3 ± 19.7 mg kg^{-1} of fresh matter), than in Spunta (180.6 ± 13.0 mg kg^{-1} f.m.) and in Spunta than in Arinda (131.6 ± 11.3 mg kg^{-1} f.m.) (Table 1). The first two values are at the limit of the guideline values proposed by some European countries. The nitrate concentration decreased with the progress of growth and "maturing" of the tuber. This may be explained with a progressive increase of day-length and sunlight intensity during the crop cycle. Nitrate reductase is most active under intense light conditions (Lorenz, 1978).