Food Chemistry 145 (2014) 903–909

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Effect of farming systems on the yield, quality parameters and sensory properties of conventionally and organically grown potato (*Solanum tuberosum* L.) tubers

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ARTICLE INFO

Article history:
Received 24 April 2013
Received in revised form 29 August 2013
Accepted 3 September 2013
Available online 11 September 2013

Keywords:
Potatoes
Conventional and organic farming
Yield
Phenolic acids
Phytophthora infestans
Sensory properties

ABSTRACT

The objectives of this two-year research were to study the impact of two different farming types, conventional and organic, on the yield and sensory properties of five Lithuanian varieties of potato tuber. The parameters and properties examined were: phenolic acids; dry matter and starch content; and the spread and intensity of *Phytophthora infestans* growth. It was determined that potato yield fluctuates with the variety, but for conventional farming it is significantly ($p < 0.05$) higher than that obtained by organic farming. The farming type has no significant effect ($p > 0.05$) on the content of phenolic acids. No significant effect ($p > 0.05$) of farming type on dry matter and starch content, or sensory properties was found. No significant relation ($p > 0.05$) was found between the content of phenolic acids and *P. infestans* spread. The spread of *P. infestans* was faster and infection was heavier in organically grown potatoes.

1. Introduction

Potatoes are among the world's most widely cultivated crops, so the conditions under which they are grown, and the impact of these conditions on qualitative and quantitative parameters of potatoes, are very important.

Most studies show that the average yields in farms engaged in organic farming are very small: less than 60% of yields obtained in conventional farms (Ninner & Horse, 1989; Sharpley, Robinson, & Smith, 1995). However, certain supporters of organic farming assert that the efficiency of organic farming nearly matches that of conventional farms (Ninner & Horse, 1989). According to Lithuanian and foreign authors, the yield of organically grown tubers decreases by between 5% and 40%, due to potato pests and diseases (Asakaviciute, Brazinskiene, & Razukas, 2013; Hansen, 2000; Razukas, Jundulas, & Asakaviciute, 2008). Quality also worsens: germination of potato tubers reduces, and storing properties deteriorate.

Potato blight, caused by the fungus *Phytophthora infestans* (Mont.) de Bary, is one of the most important potato diseases (Schepers, 2001). This disease causes serious problems in countries where high relative humidity prevails in summer, with warm days and cool nights. Potato blight causes yield losses of 15–50% every year, and during blight epiphytoty the yield loss can reach 80% (Sunseri, Johnson, & Dasgupta, 2002). The blight damage varies depending on: the locality of potato cultivation; growing conditions; weather conditions during the growing season; the disease onset time; variety resistance to blight; and volume and quality of plant protection measures (Asscheman et al., 1996; Hermansen, Hannukkala, Naerstad, & Brurberg, 2000). The main protection measures against blight are preventive, agrotechnical and chemical (Asscheman et al., 1996). Conventional agriculture receives a lot of criticism due to its chemical pollution of the environment, therefore much attention is now paid to the organic farming alternative (Hole et al., 2005).

On organic farms herbicides are banned in potato crops. Weeds in potato fields are removed by mechanical means: cutting, ploughing, cultivation and harrowing. After potato sprouting, weeds are removed by earthing up and hoeing. Appropriately chosen rotation may also reduce the number of weeds in the soil. Colorado beetles, nematodes, wireworms, and cockchafers significantly damage potato crops. Colorado beetles could be collected and destroyed (in small areas), but in larger potato cultivation

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http://dx.doi.org/10.1016/j.foodchem.2013.09.011

areas biological plant protection measures have to be used. In organic potato crops the use of synthetic pesticides, growth regulators, and genetically modified potato varieties is prohibited.

The popularity of organic foods may be attributable to the perception that they are healthier, safer and tastier than conventionally produced foods (Hajslova et al., 2005; Gilsenan, Burke, & Barry-Ryan, 2010). In order to prove this in respect of potatoes, contents of various compounds accumulated in organically and conventionally grown potato tubers are often compared. This study examined the influence of farming type on phenolic acids, which are among the most important compounds for human health. Hydroxycinnamic acid derivative and chlorogenic acid and its isomers comprise up to 90% and more of the total content of phenolic compounds determined in potato tubers. Small amounts of caffeic, ferulic and coumaric acids are also determined (Friedman, 1997; Im et al., 2008; Mattila & Hellstrom, 2007; Ramamurthy, Maiti, Thomas, & Nair, 1992). Chlorogenic acid is a very important compound for human health because it is characterised not only by antioxidant (Higdon, 2006) but also anti-cancer (LaChance, 1997), and antidiabetic effects (Chesnay, 2007) as well as other beneficial properties.

There is a growing volume of publications comparing the sensory properties of organically and conventionally grown potatoes (Gilsenan et al., 2010; Hajslova et al., 2005). However, very little attention has been given to the impact of farming type on the potato sensory profiles.

The objectives of this study were to investigate the impact of the two different farming types, conventional and organic, on the degree of potato blight development, the yield, dry matter and starch content, sensory properties and phenolic acid content of the potato tubers of five Lithuanian varieties.

2. Materials and methods

2.1. Plant material

Five Lithuanian potato varieties (*VB Venta*, *Goda*, *VB Liepa*, *VB Rasa* and *VB Aista*) were cultivated in the Voke branch of the LRCAF breeding plots with sandy loam soil on carbonated fluvioglacial eluviated gravel (JDp), according to FAO UNESCO classification – *Haplic Luvisol* (LVh) (Buividaite, 2005), with the following agrochemical characteristics: pH_{KCl} – 5.9, the content of absorbed bases – 105 mEq kg^{-1} of soil, organic matter content – 2.1%, available phosphorus (P_2O_5) – 230 mg kg^{-1} and available potassium (K_2O) – 310 mg kg^{-1}.

Potatoes were grown following traditional potato production technology in both organic and conventional farming systems. In autumn the soil was ploughed deep. In spring, after soil maturation, the field was cultivated twice, then the land was cultivated with a rotary cultivator to a depth of 0.25 m. The field was furrowed before potato planting. In the case of conventional cultivation, potatoes were locally fertilised with universal complex fertilisers (Kemira Cropcare $N_{10}P_{10}K_{20}$), and 80 kg · ha^{-1} of nitrogen, 80 kg · ha^{-1} of phosphorus and 160 kg · ha^{-1} of potassium were added at planting time. In the case of organic farming, 60 kg · ha^{-1} of nitrogen (Provita), 60 kg · ha^{-1} of phosphorus (phosphorite powder) and 90 kg · ha^{-1} of potassium (Patentkali) were inserted at planting time. After planting the interrows were hoed twice, every 7 days, using a rotary hiller. In the case of conventional farming, before the potato germination the field was sprayed with herbicide (Kernel 480 SL 3 l · ha^{-1}, active substance glyphosate 480 g · l^{-1}). Later the following pesticides were used: at the inflorescence formation (BBCH 50-55) and flowering (BBCH 62-67) stages fungicide (Ridomilas Gold 2.5 kg · ha^{-1}, active substance metalaxyl-M 40 g · kg^{-1} and mancozeb 640 g · kg^{-1}) in combination with insecticide (Actar 25 WG 0,07 kg · ha^{-1}, active substance thiamethoxam 250 g · kg^{-1}) were sprayed. In the organic farming potato field mechanical measures were used to fight weeds, and the larvae of Colorado beetles were collected by hand and destroyed.

2.2. Assessment of the degree of potato blight development

Potato blight spread and degree of development were assessed at the flowering stage BBCH 60-65 (for each tested genotype). 100 plants were evaluated. Disease intensity was measured by the OEPP/EPPO approved and recommended scale (Schepers, 2000).

Disease spread was calculated by the formula: $P = n \times 100/N$, where P – the spread of disease (%), n – number of infected plants, N – number of checked infection-free and infected plants.

Disease intensity was calculated using the following formula: $R = \Sigma(x)/N$, where R – the disease intensity (%), $\Sigma(x)$ – product sum (Σ) of the disease development percent and number of damaged plants in a certain percent group, N – number of checked infection-free and infected plants.

2.3. HPLC analysis for determination of phenolic acids

2.3.1. Chemicals

Standards of seven materials were used in the chromatographic analysis: chlorogenic acid (Chromadex, USA); caffeic acid (labour dr. Ehrenstrofer-Schafers, Germany); neochlorogenic acid; vanillic acid; trans-cinnamic acid; trans-p-coumaric acid; and trans-ferulic acid (Sigma–Aldrich Production Gmbh, Switzerland).

For extraction and chromatographic analysis gradient grade methanol (Sigma–Aldrich, Germany), purified and deionised water (18.2 mΩ cm^{-1}), produced with a Millipore (USA) water purification system, and 99.8% acetic acid (Sigma–Aldrich, Germany) were used.

2.3.2. Sample preparation

From the storage of each potato variety 5 randomly chosen tubers were taken. Washed, air-dried and sliced potato tubers were dried in a lyophilisator (Ilshin Lab Co., Ltd, Korea). Lyophilised potatoes were ground in a knife mill (Grindomix GM 200, Retsch, Germany) to a powder. When preparing an analytical sample, 1 g of the obtained powder was placed into an analytical flask and poured over with acetic acid, methanol and water (2:39:59; v/v/v) mixture to 10 ml. The mixture was then placed into an ultrasonic cleaner (Biosonic UC100, Coltene/Whaledent, USA.) for 20 min. Later the obtained potato extract was filtered first through paper and then through the membrane filter with a 0.22 μm pore size. For each potato sample three extracts were prepared.

2.3.3. Analysis

The analysis was carried out using a Waters 2695 (Waters, Milford, USA) chromatograph. For the separation of active compounds a 4.6 × 250 mm, 5 μm ACE C18 column (Advanced chromatographic Technologies, Scotland) was used. During the analysis it was kept at an external temperature control module (Waters, Milford, USA), maintaining 25 °C temperature. During the analysis 10 μl of test solution were injected. The mobile phase flow rate was 1 ml min^{-1}. The following gradient system was used: solvent A – 0.5% acetic acid in water, solvent B – methanol; 0 min – 95% A and 5% B, 40 min – 40% A and 60% B, 41 min – 10% A and 90% B, 55 min – 10% A and 90% B, 56 min – 95% A and 5% B. The separated active compounds were analysed using photodiode array detector Waters 996 PDA (Waters, Milford, USA) at a wavelength ensuring their maximum absorption: neochlorogenic acid – 324 nm, chlorogenic acid – 325 nm, caffeic acid – 323 nm, vanillic acid – 258 nm, cinnamic acid – 275 nm, coumaric acid – 309 nm, ferulic