The Effect of Fertilisation with Fermented Pig Slurry on the Quantitative and Qualitative Parameters of Tomatoes (*Solanum lycopersicum*)

Lenka KOUŘIMSKÁ[1], Luboš BABIČKA[1], Kristýna VÁCLAVÍKOVÁ[1], Daniela MIHOLOVÁ[2], Zuzana PACÁKOVÁ[3] and Martin KOUDELA[4]

[1]Department of Quality of Agricultural Products, [2]Department of Chemistry, [4]Department of Horticulture, Faculty of Agrobiology, Food and Natural Resources, [3]Department of Statistics, Faculty of Economics and Management, Czech University of Life Sciences in Prague, Prague, Czech Republic

Abstract: The effect of fertilisation with fermented pig slurry on the quantitative and qualitative parameters of two kinds of tomatoes was assessed by means of pot trials. These trials were carried out between the years 2005 and 2008. Each trial involved four treatments, namely (a) control without fertilisation, (b) fertilisation with mineral fertilisers, (c) 50% nutrients in mineral fertilisers and 50% in fermented pig slurry, and (d) fertilisation with fermented pig slurry only. Besides the yield parameters, the following characteristics were monitored: dry matter content, vitamin C content, titratable acidity, nitrogen compounds, nitrates and selected elements (Pb, Cd, As, Zn and Hg) contents. The fertilisation method showed no statistically significant influence on many parameters (titratable acidity, Hg, As, dry matter, vitamin C and nitrates contents). These results showed that anaerobically fermented pig slurry can be a suitable alternative to the use of mineral fertiliser. They also showed that its use as an organic fertiliser did not impair the hygienic quality and safety of the vegetable products grown, as all tomato samples fulfilled the tested heavy metals and nitrates legislation limits. The fertilisation method showed a statistically significant influence on the yield. Differences occurred between the organic and mineral methods in the case of Cd, and between non-fertilised and organic methods in the case of Zn. The fertilisation method also significantly influenced N-compounds content in tomatoes. A statistically significant influence of the year was found with all parameters except zinc and vitamin C contents. The influence of cultivar was also found, but only in the case of zinc and dry matter contents.

Keywords: tomato; anaerobically fermented pig slurry; fertilisation method; quantitative and qualitative parameters

Tomatoes belong to an integral part of the worldwide diet. They contain several valuable nutritional components such as antioxidants, vitamins, and minerals (Kopec 1998). On the other hand, toxic compounds and nitrates have also been reported in varying quantities in tomatoes (Chapagain *et al*. 2003; Santamaria 2006) depending on the growing conditions (Premuzic *et al.* 1998) and environmental contamination. Intensified agriculture and increasing industrialisation have resulted in the release of various pollutants, including metals, into the environment (Pustišek *et al.* 2001; Svete *et al.* 2001). The contaminants may enter the food chain (Fichet *at al.* 1999) and, consequently, elevated concentrations of heavy metals and organic substances can be found in

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 6046070901.

foodstuffs (Nasredine & Parent-Massin 2002). The exposure to toxic metals can result in acute long-term effects on health, which can be avoided when the levels of the hazardous substances in food are monitored. Therefore, it is important to pay great attention to this problem to avoid soil pollution and the danger of introducing harmful substances into the food chain of the growing media. It is also necessary to monitor particular food chains from the soil and plant production up to the final food products, in order to evaluate the contamination of the whole food chains (Petříková *et al.* 1995).

One criterion of the soil fertility and stability is the soil organic matter content. The need for improving soils and growing media productivity has highlighted the necessity for the utilization of organic wastes in the production (Picollo *et al.* 1997). The addition of organic fertilisers increases organic carbon availability stimulating biological O_2 demand (Rochette *et al.* 2000). Organic residues are considered a resource, not a waste, and their application to soil is recommended (Diez *et al.* 2000). Organic fertilisers provide better utilisation of nutrients in the soil (Klír *et al.* 1992).

Blestos and Gantidis (2004) were interested in the effect of municipal sewage sludge on the growth of transplants and fruit quality of tomatoes. The municipal sewage sludge was used in a mixture with peat as the growing medium for eggplant and tomato. The study was orientated on the possibility of the transportation of heavy metals (Cu, Zn, Mn, Pb, Cd) into the plants and fruit. From the results it is clear that the low content of all heavy metals found in tomato fruit indicates that municipal sewage sludge compost is a convenient medium for the production of tomatoes. The concentrations of heavy metals were lower than the maximal limits permitted. Al-Lahham *et al.* (2007) conducted a field experiment to investigate the extent of translocation of heavy metals to tomato fruit produced in open field with the plants being irrigated with potable water. The results of tomato fruit analysis showed increased concentrations of Fe, Cu, Ni, Mn, and Zn, but no accumulation of Cd and Pb. The accumulation of heavy metals in fruit was below the standard limits. Petersen *et al.* (2007) were interested in the recycling of livestock manure in a farm with a view to manure as a significant source of heavy metals in soil. In this case, animal feeding plays a key role as the source of Cu and Zn in the slurry applied to spray fields.

Anaerobically fermented pig slurry as the waste from basic farm industry belongs among the complex organic fertilisers with high improvement efficiency. Besides the organic compounds supply, the slurry can be a source of energy and carbon for soil microorganisms. Vallejo *et al.* (2006) also found that anaerobic digestion and separation improve the quality of pig slurry as fertiliser, being also an option to mitigate denitrification losses and N_2O emissions.

Due to the increasing number of biogas stations and the lack of literature data on the use of digestate as fertiliser for vegetables, we have discussed in this paper anaerobically fermented pig slurry as an organic fertiliser and its effects on the yield, dry matter content, vitamin C content, titratable acidity, nitrogen compounds, nitrates and selected element (Pb, Cd, As, Zn and Hg) contents in tomatoes.

The objective of this study was to find out if anaerobically fermented pig slurry could be a suitable replacement for mineral inorganic fertilisers from the quantitative and qualitative point of view.

MATERIAL AND METHODS

Seeds of tomato (*Lycopersicon lycopersicum* L.) cultivars: Start F1 and Tornádo F1 were purchased from Semo Smržice Ltd. (Smržice, Czech Republic) and grown in greenhouses. Tomato plants (size 30 cm) were then planted out into 20 l pots in Peat-bark substrate RKS I (Agro CS Inc.). The substrate was enriched with fertilisers according to the respective fertilising methods. Ten plants were grown with each of the following fertilising treatments:

(a) Control (marked N) – no fertiliser added.

(b) Mineral (marked M) – 15 g $(NH_4)_2SO_4$ and 9 g K_2HPO_4 were added to each pot (20 l) prior to planting. 7.5 g $(NH_4)_2SO_4$ per each pot was added 30 days later.

(c) Combined (marked K) – 50% of mineral (7.5 g $(NH_4)_2SO_4$ and 4.5 g K_2HPO_4) and 50% of organic fertilizers (0.4 l of fermented pig slurry) were added to each pot prior to planting. 3.75 g $(NH_4)_2SO_4$ and 1.5 l of fermented pig slurry per each pot were added later 30 days after planting.

(d) Organic (marked O) – 0.8 l of fermented pig slurry was added to each pot which was done prior to planting. 2 l of the same organic fertiliser per each pot was added 30 days later.

The anaerobically fermented pig slurry was obtained from a biogas station (R.A.B. Ltd., Třeboň, Czech Republic) processing pig slurry from a swinery. The biogas station works continually with the same input, the composition of the anaerobically fermented pig slurry was according to the data from the supplier: 595 mg NH_4^+ per litre, 755 mg PO_4^{3-} per litre and 1.1–1.25 g K_2O per litre. The anaerobically fermented pig slurry also fulfilled the limits for the risk elements contents (Decree No. 185/2001 of 5 May 2001 about wastes and about changes of some other codes and Decree No. 9/2009 of 12 December 2008 setting changes of Decree No. 156/1998 about fertilizers. Collection of Law, Ministry of the Interior CR).

There were 10 tomato plants for each cultivar and fertilising method. The experiments were carried out over a period of four years (2005–2008), which represents a total of 320 tomato plants.

The analysis of heavy metals was done by the AAS method (Miholová *et al.* 1996). Dry matter content was determined by drying (102 ± 2°C, constant weight at difference less than 1 mg) (Davídek & Velíšek 1992), titratable acidity by titration with 0.1M NaOH (calculated as citric acid content), vitamin C content by HPLC (Purospher RP-18 (5 µm) 125 × 4 mm column, Purospher RP-18e (5 µm) 4 × 4 mm pre-column, mobile phase 5% methanol and 95% distilled water, flow 0.8 ml/min, column temperature 35°C, injected volume 5 µl, UV detection at 251 nm). Nitrates were determined by the ion-selective electrode (ISE) method (Turbow *et al.* 2002); $NaNO_3$ was used as the calibration standard. The nitrogen compounds (N-compounds) content was determined acidimetrically by the Kjeldahl method and calculated from the nitrogen content (ISO 1871 1975).

The results were analysed using multifactorial analysis of variance (ANOVA), which was used to find out the influence of three factors (year, fertilisation method, and cultivar). For multiple comparison of the groups, the Bonferroni method was used. *P*-values < 0.05 were regarded as statistically significant. The results were analysed using the statistical software SPSS Statistics 17.

RESULTS AND DISCUSSION

The basic statistical characteristics (mean and standard deviation S.D.) of analysed parameters in to the respective fertilisation methods are given in Tables 1 and 2. The analytically found relation contents are in accordance with the literature data

Table 1. Descriptive statistics of the results in relation to the fertilising method (control and organic tomato samples)

Parameter	Control (N)		Organic (O)	
	mean	SD	mean	SD
Yield from 10 plants (kg)	7.82	2.90	15.87	11.52
Yield from 10 plants (fruit pieces)	153	57	244	134
Hg (mg/kg of d.m.)	0.0029	0.0042	0.0049	0.0124
As (mg/kg of d.m.)	0.0271	0.0283	0.0194	0.0143
Cd (mg/kg of d.m.)	0.0982	0.0528	0.0821	0.0464
Zn (mg/kg of d.m.)	20.83	2.26	29.96	11.69
Dry matter content (%)	5.84	0.56	6.00	0.51
Vitamin C (mg/kg)	214.7	78.8	272.4	55.36
N-compounds (% in d.m.)	13.76	1.73	16.61	1.37
Nitrates (mg/kg)	15.03	7.59	20.25	7.91
Titratable acidity (g/100 g)	0.442	0.122	0.423	0.101

d.m. = dry matter; SD – standard deviation

Table 2. Descriptive statistics of the results in relation to the fertilising method (mineral and combined tomato samples)

Parameter	Mineral (M)		Combined (C)	
	mean	SD	mean	SD
Yield from 10 plants (kg)	18.97	11.11	20.26	7.90
Yield from 10 plants (fruit pieces)	274	113	302	66
Hg (mg/kg of d.m.)	0.0014	0.0024	0.0032	0.0041
As (mg/kg of d.m.)	0.0239	0.0232	0.0295	0.0204
Cd (mg/kg of d.m.)	0.1351	0.0683	0.1226	0.0380
Zn (mg/kg of d.m.)	28.50	5.21	26.98	4.38
Dry matter content (%)	5.51	0.75	5.86	0.55
Vitamin C (mg/kg)	231.7	47.2	278.9	51.36
N-compounds (% in d.m.)	22.06	2.02	16.26	1.77
Nitrates (mg/kg)	16.93	7.76	15.31	5.26
Titratable acidity (g/100 g)	0.462	0.099	0.425	0.091

d.m. = dry matter; SD – standard deviation

(Castaldi & Melis 2004; Demirezen & Aksoy 2006; Bronkowska *et al.* 2008; Majkowska-Gadomska *et al.* 2008).

As concerns the quantitative parameters for all four years, the fertilisation method used showed a statistically significant influence on the yield (P_{kg} = 0.003, P_{pieces} = 0.004). The highest yield of tomatoes (both in kilograms and in the fruit pieces) was achieved with the combined fertilisation method while the lowest one was with no fertiliser use. Quantitative parameters for organic and mineral methods were not much different. Statistically significant differences in the yield (kg) were proved between the non-fertilised and mineral methods (P = 0.009), and non-fertilised and combined methods (P = 0.003), which shows the positive effect of the use of fertilisers on the tomatoes yield. Any significant difference between the organic and mineral or combined method was not found.

Fertilisation with anaerobically fermented pig slurry does not generally increase the amounts of heavy metals found in tomatoes, which confirms the results published by Al-Laham *et al.* (2007). From the qualitative point of view, all tomato samples fulfilled the heavy metals limits for the tested elements and nitrates limits (Regulation No. 305/2004 of 6 May 2004 setting kinds of contaminating and toxicologically important compounds and their maximum levels in foodstuffs, Collection of Law, Ministry of the Interior CR and Commission Regulation (EC) No. 1881/2006). The lead content values in all samples did not exceed 0.1 mg/kg of fresh matter. The fertilisation method showed a statistically significant influence on cadmium and zinc concentrations in tomatoes (P_{Cd} = 0.035, P_{Zn} = 0.039). There were differences between the organic and mineral methods in the case of Cd (P = 0.049), and between the non-fertilised and organic methods in the case of Zn (P = 0.047). A higher Zn content in organic tomatoes reflects the zinc supplementation to the pigs' diet (Regulation (EC) No. 1831/2003). On the other hand, a higher Cd content in mineral samples can indicate possible competition between these two elements in tomatoes metabolism.

The fertilisation method significantly influenced the N-compounds content in tomatoes ($P < 0.0001$). The differences were found between the non-fertilised and fertilised methods ($P < 0.01$), between organic and mineral methods ($P < 0.0001$), and between mineral and combined methods ($P < 0.0001$). The minerally fertilised tomatoes had the highest N-compounds content. This may have been caused by different forms of nitrogen in anaerobically fermented slurry (liquid NH_4^+ form) and in mineral fertilisers (solid NO_3^- form).

The fertilisation method showed no statistically significant influence in the case of other parameters (titratable acidity, Hg, As, dry matter, vitamin C and nitrates contents).

The year showed a statistically significant influence ($P < 0.05$) on all parameters except zinc and vitamin C, which confirms the importance of the weather, and the reason why the experiment was repeated over four years.

The influence of cultivar was also found. Statistical significance was discovered in the case of dry matter content ($P = 0.002$). The Start F1 cultivar had a higher average dry matter content (6.04 ± 0.40 g per 100 grams) as compared to the Tornádo F1 tomatoes (5.57 ± 0.65 g per 100 grams). Majkowska-Gadomska *et al.* (2008) also confirmed that the dry matter content significantly depends on the tomato fruit cultivar. As published by Ordonez-Santos *et al.* (2009) who compared ecologically and conventionally produced tomatoes, statistically significant differences occurred rather between cultivars than between tomatoes grown under the use of different management practices.

CONCLUSION

This study was conducted to evaluate the use of fermented pig slurry as a part of the growth media for vegetable production and to estimate the qualitative and quantitative impacts on the production. By monitoring quantitative tomato values, the fertilisation method showed a statistically significant influence on the yield but no significant difference was shown between organic and mineral or combined methods.

From the qualitative point of view, all tomato samples fulfilled the legislative limits for the parameters tested. The fertilisation method significantly influenced N-compounds content in tomatoes. Also a difference was observed between the organic and mineral methods in the case of zinc content. The effect of the tomato cultivar was found in the case of the dry matter content. However, the effect of the year had a predominant influence on many of the data evaluated.

As no statistically significant influence of the fertilisation method was found in the case of many parameters tested (titratable acidity, Hg, As, dry matter, vitamin C and nitrates content), it can be concluded that the anaerobically fermented pig slurry can be a suitable alternative to conventional mineral fertilisers for tomatoes fertilisation. Our study shows that the anaerobically fermented pig slurry may constitute an alternative to inorganic fertilisers if the used amounts of both inorganic and organic fertilisers contain the same level of nitrogen.

References

Al-Lahham O., Assi N.M., Fayyad M. (2007): Translocation of heavy metals to tomato (*Solanum lycopersicum L.*) fruit irrigated with treated wastewater. Scientia Horticulturae, **113**: 250–254.

Bletsos F.A., Gantidis N.D. (2004): The effect of municipal sewage sludge on growth of transplants and fruit quality of eggplant (*Solanum melongena*) and tomato (*Lycopersicon esculentum*). Agrochimica, **48**: 104–114.

Bronkowska M., Figurska-Ciura D., Orzel D., Styczynska M., Wyka J., Lozna K., Zechalko-Czajkowska A., Biernat J. (2008): Evaluation of plant products from the Legnicko-Glogowski region for their contamination with arsenic. Food Chemistry, **109**: 4–7.

Castaldi P., Melis P. (2004): Growth and yield characteristics and heavy metal content on tomatoes grown in different growing media. Communications in soil science and plant analysis, **35**: 85–98.

Chapagain B.P., Wiesman Z., Zaccai M., Imas P., Magen H. (2003): Potassium chloride enhances fruit appearance and improves quality of fertigated greenhouse tomato as compared to potassium nitrate. Journal of Plant Nutrition, **26**: 643–658.

Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Union, The Commission of the European Communities, Brussels, L364/5–L364/24.

Davídek J., Velíšek J. (1992): Food Analysis. VŠCHT, Praha. (in Czech)

Demirezen D., Aksoy A. (2006): Heavy metal levels in vegetables in Turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. Journal of Food Quality, **29**: 252–265.

Diez J.A., Caballero R., Román R., Tarquis A., Cartagena M.C., Vallejo A. (2000): Integrated fertilizer and irrigation management to reduce nitrate leaching in Central Spain. Journal of Environmental Quality, **29**: 1539–1547.

Fichet D., Boucher G., Radenac G., Miramand P. (1999): Concentration and mobilisation of Cd, Cu, Pb and Zn by meiofauna populations living in harbour sediment: their role in the heavy metal flux from sediment to food web. Science of the Total Environment, **244**: 263–272.

ISO 1871 (1975): Agricultural food products – General directions for the determination of nitrogen by the Kjeldahl method. European Committee for Standardization, Brussels.

Klír J., Růžek P., Zámečníková B. (1992): The Role of Nitrogen in Plant Nutrition. VÚRV, Praha, 78–90. (in Czech)

Kopec K. (1998): Tables of Fruit and Vegetables Nutritional Values. UZPI, Praha. (in Czech)

Majkowska-Gadomska J., Francke A., Wierzbicka B. (2008): Effect of soil substrate on the chemical composition of fruit of some tomato cultivars grown in an unheated plastic tunnel. Journal of Elementology, **13**: 261–267.

Miholová D., Slámová A., Száková J., Svatoš Z., Mader P. (1996): International pant-analytical exchange and quality assurance in a trace element laboratory. Communications in Soil Science and Plant Analysis, **27**: 891-906.

Nasreddine L., Parent-Massin D. (2002): Food contamination by metals and pesticides in the European Union. Should we worry? Toxicology Letters, **127**: 29–41.

Ordonez-Santos L.E., Arbones-Macineira E., Fernandez-Perejon J., Lombardero-Fernandez M., Vazquez-Oderiz L., Romero-Rodriguez A. (2009): Comparison of physicochemical, microscopic and sensory characteristics of ecologically and conventionally grown crops of two cultivars of tomato (*Lycopersicon esculentum* Mill.). Journal of the Science of Food and Agriculture, **89**: 743–749.

Petersen S.O., Sommer S.G., Beline F., Burton C., Dach J., Dourmad J.Y., Leip A., Misselbrook T., Nicholson F., Poulsen H.D., Provolo G., Sorensen P., Vinneras B., Weiske A., Bernal M.P., Bohm R., Juhasz C., Mihelic R. (2007): Recycling of livestock manure in a whole-farm perspective. Livestock Science, **112**: 180–191.

Petříková V., Ustjak S., Roth J. (1995): Heavy metals contamination of agricultural crops and soils in five regions of the Czech Republic with different immission pollution load. Rostlinná výroba, **41**: 17–23. (in Czech)

Piccolo A., Pietramellara G., Mgabwu J.S.C. (1997): Use of humic substances as soil conditioners to increase aggregate stability. Geoderma, **75**: 267–277.

Premuzic Z., Bargiela M., Garcia A., Rendina A., Iorio A. (1998): Calcium, iron, potassium, phosphorous, and vitamin C content of organic and hydroponic tomatoes. Horticultural Sciences, **33**: 255–257.

Pustišek N., Milačič R., Veber M. (2001): Use of the BCR three-step extraction procedure for the study of the partitioning of Cd, Pb and Za in various soil samples. Journal of Soils Sediments, **1**: 25.

Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition. Official Journal of the European Union, The European Parliament and the Council of the European Union, Brussels, L268/29–L268/43.

Rochette P., van Bochove E., Prevost D., Angers D.A., Cote D., Bertrand N. (2000): Soil carbon and nitrogen dynamics following application of pig slurry for the 19th consecutive year. II. Nitrous oxide fluxes and mineral nitrogen. Soil Science Society of America Journal, **64**: 1396–1403.

Santamaria P. (2006): Nitrate in vegetables: toxicity, content, intake and EC regulation. Journal of the Science of Food and Agriculture, **86**: 10–17.

Svete P., Milacic R., Pihlar B. (2001): Partitioning of Zn, Pb and Cd in river sediments from a lead and zinc mining area using the BCR three-step sequential extraction procedure. Journal of Environmental Monitoring, **3**: 586–590.

Turbow S.B., Wehmeier G.H., Block D.E. (2002): Comparison of enzymatic and ISE methods for ammonia measurements in untreated red and white juices and wines. American Journal of Enology and Viticulture, **53**: 158–162.

Vallejo A., Skiba U.M., Garcia-Torres L., Arce A., Lopez-Fernandez S., Sanchez-Martin L. (2006): Nitrogen oxides emission from soils bearing a potato crop as influenced by fertilization with treated pig slurries and composts. Soil Biology & Biochemistry, **38**: 2782–2793.

Received for publication November 26, 2007
Accepted after corrections August 20, 2009

Corresponding author:

Ing. Lenka Kouřimská, Ph.D., Česká zemědělská univerzita v Praze, Fakulta agrobiologie, potravinových a přírodních zdrojů, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 224 383 511, fax: + 420 224 382 891, e-mail: kourimska@af.czu.cz