Effects of Tomato Pomace Composts on Yield and Quality of Processing Tomato (*Lycopersicon esculentum* Mill.)

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Abstract

Organic farming encourages the use of organic waste materials as substitutes for chemical fertilizers. Tomato pomace presents an alternative to inorganic fertilizer. A field experiment was carried out to evaluate the influence of tomato pomace composts and nitrogen fertilization on agronomic and quality parameters of the processing tomato. The experiment was laid out in a randomized complete block design with three replications and five fertilization treatments (untreated, nitrogen fertilizer, tomato pomace with biocyclic humus soil, tomato pomace with manure and tomato pomace with plant residues). The results showed that the highest average fruit weight and fruit yield (163.4 t/ha) were found in plots subjected to nitrogen fertilization, while the highest total soluble solids content (4.29 °Brix), and L^* and a^* colour parameters, important quality parameters to processing tomato industry, were obtained through the application of tomato pomace mixed with biocyclic humus soil making organic tomatoes suitable for processing tomato industry.

Keywords: Heinz 3402 F₁, surface colour, tomato pomace compost, total soluble solids

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Introduction

The management of processing waste constitutes a significant issue facing the food industry. Within the European Union, the food sector produces approximately 250 million tons of by-products and waste per year, of which 10% remain after the fruit and vegetable processing (Fava *et al.*, 2015). Moreover, 30-50% of those by-products and waste come from fruit and vegetable juice production (Kasapidou *et al.*, 2014). The global food production and thereby the amount of food waste is expected to rise, requiring an increased attention. Currently, the application of waste streams partially includes the use as feed for livestock, plant fertilizer, composting, biogas material, or as a source of pectic polysaccharides

or general dietary fiber, however; a large part of them are still incinerated or landfilled. As a result, they do not produce value for farmers, but result in a loss of billions of euros in waste management and cause environmental pollution (Mirabella *et al.*, 2014).

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely cultivated crops with a world production of over 182 million tons in 2017 (FAOSTAT, 2019). Significant amounts of tomato are processed yearly to produce tomato juice, paste, purée, ketchup, sauce, and salsa, resulting in the generation of large quantities of a by-product, known as tomato pomace (Del Valle *et al.*, 2006). Tomato pomace represents, at most, 5-10% of the fruit weight and is composed of around 33%

seed, 27% skin, and 40% pulp (Kaur *et al.*, 2008). Tomato pomace comprises 15.4-23.7% total protein, 25.4-50.0% fiber, 5.4-20.5% total fat, and 4.4-6.8% mineral content on a dry matter basis. Due to its high protein content, this by-product represents an important fodder for livestock (Weiss *et al.*, 1997).

Tomato pomace also presents an alternative to inorganic fertilizer. It is possible to use tomato pomace as a soil amendment because of its high organic matter and low toxic element content. Risks of plant pathogen dissemination and phytotoxicity hazards are eliminated when an effective sanitation of tomato waste is achieved through a composting process before the amendment to soil (Avgelis and Manios, 1989). Composting can suppress pathogens and stabilize organic matter because of the higher temperatures and the growth of aerobic microorganisms. According to the literature, a C/N ratio of 20-30 is recommended for digested materials (Sheets *et al.*, 2015). Tomato pomace contains a high nitrogen concentration and has C/N ratio of about 11 (Van Horn, 1995). Therefore, tomato pomace should be co-composted with dry and carbon rich bulking agents to adjust this C/N ratio. Several additions have been successfully applied to balance the initial C/N ratio, such as wheat straw and separated dairy manures (Kulcu, 2014) and cattle manure and sawdust (Kalamdhad *et al.*, 2009). Fertilizer quality and profits of compost obtained from tomato pomace can be further improved by supplementing them with humic substances that

are beneficial to plants. Humic substances can increase plant growth or even make a crop less sensitive to stressful conditions by several modes of action, such as activation of numerous plant metabolism pathways, stimulation of microbial activity and enhanced production of growth regulators in plants (Ertani *et al.*, 2013).

Sustainable agriculture encourages the use of waste materials as substitutes for chemical fertilizers. This may be an effective way to use the high volumes of waste organic materials from tomato processing and is therefore of potentially significant environmental value. The objective of this study was to evaluate the influence of tomato pomace composts and nitrogen fertilization on agronomic and quality parameters of the processing tomato.

Materials and methods

A field experiment was carried out in the organic experimental field of Agricultural University of Athens (Latitude: 37° 59' N, Longitude: 23° 42' E, Altitude: 29 m above sea level) from May until August 2019. The soil was a clay loam (29.8% clay, 34.3% silt and 35.9% sand) with pH (1:1 H₂O) 7.21, nitrate-nitrogen (NO₃-N) 11.2 mg kg⁻¹ soil, available phosphorus (P) 52 mg kg⁻¹ soil, available potassium (K) 33.7 mg kg⁻¹ soil, 16.94% CaCO₃ and 1.57% organic matter. Weather data (mean monthly temperature and precipitation) during the growing period were obtained from the weather station of Agricultural University of Athens and are shown in Figure 1. The mean

Figure 1. Weather data (mean monthly air temperature and precipitation) during the growing season (May-August, 2019)

monthly temperature and total rainfall during the growing period were 26.1°C and 5.8 mm, respectively.

The experiment was set up on an area of 187 m² according to a randomized complete block design (RCBD), with three replications and five fertilization treatments: control (untreated), tomato pomace with biocyclic humus soil [50% tomato pomace + 50% biocyclic humus soil (Biocyclic Park, Kalamata, Greece)] at a rate of 2000 kg ha⁻¹, tomato pomace with manure [50% tomato pomace + 50%, tomato pomace with farmyard manure (solid, 1.53% N)] at a rate of 2000 kg ha⁻¹, tomato pomace with plant residues [50% tomato pomace + 50% plant residues (50% wheat straw + 50% maize straw)] at a rate of 2000 kg ha⁻¹, and inorganic nitrogen fertilizer (Nutrimore Winner 40-0-0+14.5 SO₃, Gavriel Ltd.) at a rate of 250 kg ha⁻¹. The characteristics of tomato pomace composts used as soil amendments are shown in Table 1.

The plot size was 9 m² (3 × 3 m). There was a space of 0.5 m between plots and 1 m between replications. Soil was prepared by ploughing at a depth of about 25 cm. One day before transplanting, the fertilizers were applied by hand to the soil surface and then harrowed in. Transplanting of tomato seedlings into the field was done on 2 May 2019. Tomato seedlings (*Lycopersicon esculentum* Mill. cv. Heinz 3402 F₁) were transplanted by hand 50 cm between rows and 30 cm between plants per row. A drip irrigation system was also set up on the field. The total quantity of water applied during the cultivation periods was 846 mm. Throughout the experimental period, there was no incidence of pest or disease on processing tomato crop. Finally, weeds were controlled by hand hoeing when it was necessary.

Tomato fruits were harvested at 118 days after transplanting (DAT). Fruit number per plant, average fruit weight, fruit diameter as well as fruit yield were determined by using five randomly selected plants from each plot. Fruit diameter (mm) was measured with a Starrett EC799A-6/150 electronic digital caliper (L.S. Starrett Co., Athol, MA, USA) having an accuracy of 0.02 mm.

The qualitative parameters were assessed using five fruits per plant from three randomly selected plants from each plot. Fruit skin colour measurements were performed using a Minolta CR-300 tristimulus colorimeter (Konica Minolta, Inc., Sakai, Osaka 590-8551, Japan). Colour was recorded according to the CIE-L*a*b* colour space system. Two measurements were made at the equatorial region of the pericarp of each fruit and the mean values were calculated. Colour index (CI) was calculated using the following formula (Jimenez-Cuesta *et al.*, 1981):

$$CI = 1000 a^*L^{*-1}b^{*-1}$$

Fruit firmness was measured at the equatorial region by recording the force required to insert a 6.3 mm-diameter conical needle to a depth of 0.6 cm in the fruit using a Chatillon DFIS 10 penetrometer connected to a Chatillon TCM 201-M motorized force test stand (John Chatillon and Sons, Inc., Greensboro, NC 27425, USA) and moving at a constant speed of 200 mm min⁻¹.

Total soluble solids (TSS) content was measured at 20°C with a Schmidt & Haensch HR32B hand-held refractometer (Schmid & Haensch GmbH & Co., 13403 Berlin, Germany) having a sensitivity of 0.2 °Brix. Titratable acidity (TA) was determined by titrating 10 ml of diluted tomato pulp with N/50 NaOH using 1% phenolphthalein indicator.

Table 1. Characteristics of tomato pomace composts used as soil amendments

	Organic Matter (%)	EC (mS/cm)	pH	N total (%)	P Olsen (mg kg ⁻¹)	K (mg kg ⁻¹)	Mg (mg kg ⁻¹)
Tomato pomace with biocyclic humus soil	51	1.71	7.28	2.78	14	31	0.78
Tomato pomace with manure	44	1.68	7.41	3.10	21	33	0.66
Tomato pomace with plant residues	45	1.74	7.36	2.88	16	31	0.32

The experimental data were analyzed using the SigmaPlot 12 statistical software (Systat Software Inc., San Jose, CA, USA) according to the randomized complete block design (RCBD). Values were compared by analysis of variance (ANOVA) and differences between means were separated using the Least Significant Difference (LSD) test. Correlation analyses were used to describe the relationships between yield and quality characteristics using Pearson's correlation. All comparisons were made at the 5% level of significance ($p \leq 0.05$).

Results and discussion

The fruit number per plant is presented in Figure 2a. The effect of different fertilization regimes was found to be statistically significant ($F=8.74$, $p=0.017$). In particular, the highest number of fruits per plant (58.3) was achieved in plots fertilized with inorganic fertilizer, while the

lowest value (47.8) was found in the unfertilized (control) treatment. The results obtained concur with earlier findings of Patil *et al.* (2004) and Bilalis *et al.* (2018).

The average fruit weight differed among the fertilization treatments ($F=6.10$, $p=0.036$). with highest value (62.2 g) obtained in the inorganic treatment followed by tomato pomace mixed with biocyclic humus soil (52.6 g) and tomato pomace mixed with manure (53.7). The lowest value (38.7) was observed in untreated plants (Fig. 2b). In an experiment conducted under tropical andosol soil conditions, it was found that the weight of tomato fruits was not influenced by fertilization regimes or cultivars (Tonfack *et al.*, 2009). The differences among those findings could be related to the variation in cultivars, soil type, temperature and rainfall during the growing periods of those experiments.

Figure 2. Effects of fertilization [control, inorganic nitrogen fertilizer, tomato pomace mixed with biocyclic humus soil (TP + BHS), tomato pomace mixed with manure (TP + Manure) and tomato pomace mixed with plant residues (TP + Residues)] on a) fruit number per plant, b) average fruit yield, c) fruit diameter and d) fruit yield. Vertical lines represent standard mean errors. Different low-case letters denote statistically significant differences according to the LSD test ($p \leq 0.05$).

Concerning the fruit diameter, there were no significant differences among fertilization treatments ($F=0.32$, $p=0.849$). Despite that, the highest fruit diameter (3.76 cm) was observed in plants fertilized with the inorganic nitrogen fertilizer (Fig. 2c). This characteristic is dependent on cultivar genotype (Bilalis *et al.*, 2018).

The analysis of variance revealed that fruit yield was actually affected by the different fertilization regimes ($F=9.45$, $p=0.014$). Specifically, the highest yield (163.4 t ha⁻¹) was found in plots fertilized with inorganic nitrogen fertilizer followed by tomato pomace mixed with biocyclic humus soil (150.7 t ha⁻¹) (Fig. 2d). Tomato plants fertilized with inorganic fertilizers produced higher fruit yield, since inorganic fertilizers contained soluble inorganic nitrogen with quick availability for plants (Murmu *et al.*, 2013; Ronga *et al.*, 2017). Fruit yield had a significant and positive correlation with

fruit number ($r=0.74$, $p=0.013$) and average fruit weight ($r=0.97$, $p<0.001$).

Fruit firmness is one of the most important quality traits of tomato processed in the canning industry, especially, of canned whole tomatoes. Fruit firmness, was not affected by fertilization ($F=1.82$, $p=0.263$); however, the highest value (4.53 kg cm⁻²) was obtained in untreated plots, while the lowest value (4.46 kg cm⁻²) was found in plots treated with inorganic nitrogen fertilizer (Fig. 3a). Knee *et al.* (2002) reported that fruit firmness is negatively correlated with the increase of nitrogen content in fruits. A significant and positive correlation was observed between fruit firmness and average fruit weight ($r=0.73$, $p=0.016$).

The soluble solids are important for tomato quality and for processed concentrate as they influence sweetness, sourness and flavor

Figure 3. Effects of fertilization [control, inorganic nitrogen fertilizer, tomato pomace mixed with biocyclic humus soil (TP + BHS), tomato pomace mixed with manure (TP + Manure) and tomato pomace mixed with plant residues (TP + Residues)] on a) fruit firmness, b) total soluble solids (TSS) and c) titratable acidity (TA). Vertical lines represent standard mean errors. Different low-case letters denote statistically significant differences according to the *LSD* test ($p \leq 0.05$).

intensity. Total soluble solids (TSS) is composed of a mixture of predominate sugars (65%), acids (13%) and other compounds (mainly amino acids, ascorbate, minerals, pectins, and phenols) which increase the colour and maturity (Beckles, 2012). According to the analysis of variance, TSS content was significantly affected by fertilization ($F=7.24$, $p=0.026$) with the highest value (4.29 °Brix) observed in tomatoes fertilized with tomato pomace mixed with biocyclic humus soil (Figure 3). These results are in line with Barrett *et al.* (2007) who reported that there was a higher TSS content in processing tomatoes grown organically in comparison to those chemically fertilized. In addition, humic substances, contained in biocyclic humus soil, stimulated photosynthesis, with the result that there were more assimilates for the tomato fruits which increased TSS content (Eisenbach *et al.*, 2019).

Titrateable acidity is an important quality parameter contributing to the flavor of tomato products. This trait was significantly affected by different fertilization regimes ($F=4.33$, $p=0.041$) with the values being 0.249%, 0.246%, 0.244%, 0.243% and 0.241 % citric acid w/w for tomato pomace mixed with biocyclic humus soil, tomato pomace mixed with manure, tomato pomace mixed with plant residues, inorganic fertilizer and untreated variants, respectively (Fig. 3c). These results are in accordance with other studies which found that tomatoes grown in nitrate-dominant fertilizer solutions had significantly lower values of titrateable acidity than those grown fertilized with organic fertilizers (Barrett *et al.*, 2007; Bilalis *et al.*, 2018).

Tomato fruit colour is one of the essential and quality characteristics of the fruit and relates primarily to the lycopene content (Garcia and

Figure 4. Effects of fertilization [control, inorganic nitrogen fertilizer, tomato pomace mixed with biocyclic humus soil (TP + BHS), tomato pomace mixed with manure (TP + Manure) and tomato pomace mixed with plant residues (TP + Residues)] on fruit surface color: a) L value, b) a value, c) b and d) Colour Index (CI). Vertical lines represent standard mean errors. Different low-case letters denote statistically significant differences according to the LSD test ($p \leq 0.05$).

Barrett, 2006). In the present experiment, colour lightness (L^*) was significantly influenced by the different fertilization treatments ($F=11.54$, $p=0.009$). The highest value (42.6) was found in tomatoes treated with tomato pomace mixed with biocyclic humus soil, indicating that the red colour of those tomatoes was lighter (Fig. 4a). A positive and significant correlation was found between lightness and total soluble solids ($r=0.87$, $p=0.021$). Concerning a^* value which represents the green-red component ($a^*>0$ red, $a^*<0$ green), it was significantly different among fertilization regimes ($F=7.07$, $p=0.027$). The data showed that the tomatoes fertilized with tomato pomace mixed with biocyclic humus soil presented the highest value (34.74) (Fig. 4b). The a^* value has the tendency to increase during ripening stage, as the red colour is the result of lycopene synthesis (Garcia and Barrett, 2006). A significant and positive correlation was found between a^* value and total soluble solids ($r=0.98$, $p<0.001$). The b^* value represents the difference between blue ($-b^*$) and yellow ($+b^*$). This value, which has the tendency to increase from the breaker to turning-stage and then to decrease until the red stage, was not affected by different fertilization treatments ($F=0.51$, $p=0.731$) with the values ranging 25.97 to 26.38 (Fig. 4c). The Colour Index that presents a high correlation with the external visual colour of fruit, was also not influenced by fertilization ($F=0.69$, $p=0.629$); however, the highest value (31.92) was observed in the untreated plot, while the lowest (30.97) in tomato pomace mixed with biocyclic humus soil (Fig. 4d).

Conclusion

The results of the present study indicated that the yield and quality parameters of processing tomato were significantly affected by the different fertilization regimes. The highest yield parameters were observed under nitrogen fertilization, while the highest total soluble solids content as well as L^* and a^* colour parameters, important quality parameters to processing tomato industry, were found in plots treated with tomato pomace mixed with biocyclic humus soil making organic tomatoes suitable for processing tomato industry. Further studies are needed in order to investigate the seasonality and cultivar effects.

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