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INFLUENCE OF CONVENTIONAL AND BIOLOGICAL CONTROL ON POSTHARVEST QUALITY OF TOMATOES

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Abstract

The objective of this experiment was to evaluate the efficacy of some chemical and biological products used in the control of foliar pathogens in tomato crop in greenhouse and their influence on the quality and shelf life of tomato fruits. Conventional products ensured a much higher efficay (>90%) compared to biological ones (<67%). The high moisture content of the fruits contributes to their relatively short shelf life. Water loss not only accelerates the aging process of the fruits but also impacts their quality. This research systematically examines variations in water content, total dry matter, total soluble solids, organic acids, and firmness in tomatoes stored at temperatures of 6°C and 22°C, starting from the time of harvest and extending for 3, 5, 7, and 10 days. Observations indicated that water loss, evidenced by reduced firmness and fruit weight, was associated with an increase in soluble solids and total dry weigt per unit mass. Additionally, the degradation of organic acids in tomatoes was influenced by the storage duration, with increasing temperatures accelerating these transformations.

Key words: *Solanum lycopersicum, biological and conventional control, storage temperatures, postharvest quality.*

INTRODUCTION

Tomatoes (*Solanum lycopersicum*) are among the most consumed vegetables worldwide, playing an important role in human nutrition due to their high content of nutrients and bioactive phytochemicals, such as vitamins C and E and lycopene (Ebert, 2020).

By 2030, the European Union aims to reduce the use of chemical pesticides by up to 50% (Bremmer et al., 2021; Pânzaru et al., 2023).

Organic agriculture is a dynamic sector in Romania that has seen an upward evolution in recent years. Romanian agricultural research gives special importance to the development of technologies for the cultivation of vegetables grown in conventional and/or ecological agriculture. Good results were obtained in biological control of disases and pests on tomatoes (Bratu et al., 2015, Hogea, 2020), pepper (Călin et al., 2017; 2020), eggplants (Iosob & Cristea, 2022), cucumbers (Cenușă et al., 2016), melons (Șovărel et al., 2024), cabbage (Iosob et al., 2023), zucchini (Șovărel et al., 2024) and onion (Călin et al., 2016).

Global tomato production has increased by approximately 13% in the last decade, according to FAOSTAT (2025). The demand for tomatoes with superior organoleptic qualities continues to grow, highlighting the need for appropriate management of this crop (Fenech et al., 2019; Wang et al., 2023). Organoleptic parameters are influenced by growing conditions, ripening stage, and post-harvest processing technologies (Cause et al., 2010; Chaïb et al., 2007; Zushi & Higashijima, 2022). As climacteric fruits, tomatoes continue to ripen after harvest, with a tendency to quickly become overripe and vulnerable to spoilage (Bourne, 2006). Their shelf life is usually between 2 and 3 weeks, and after harvest, they undergo significant chemical changes (Anyasi et al., 2016; Thole et al., 2020; Tolasa et al., 2021; Vunnam et al., 2014). Quality deterioration is influenced by bacteria, yeasts, molds, and viruses (Fiddler, 1982). Although global production has increased, post-harvest losses remain a major challenge, with estimates ranging from 20% to 50%, depending on storage and handling (Kader, 1985; Albornoz et al., 2019). Thus, extending shelf life and improvingquality are essential objectives that impact farmers' incomes and global food security.

Post-harvest quality deterioration of tomatoes is influenced by temperature and storage time. Low-temperature storage is crucial for maintaining quality (Bourne, 2006). The optimal temperature for storing tomatoes is close to 0 °C; an increase of 10 °C can triple the rate of deterioration. However, Chira (1999) indicates that the ideal refrigeration temperature varies between 0.5 and 13°C, depending on the stage of ripening. Immediate post-harvest cooling is essential for quality preservation (Kader et al., 1985), helping to maintain organoleptic characteristics that are crucial for consumer satisfaction (Colantonio et al., 2022; Wang et al., 2023). Proper management of temperature and relative humidity is also essential to prevent rapid spoilage of tomatoes and to ensure global food security (Mrema & Rolle, 2002; Hatami et al., 2013; Morgan, 2021). Implementing effective temperature and humidity management strategies can maintain product quality and reduce the economic impact associated with spoilage (Alia-Tejacal et al., 2007; Kabir et al., 2020; Morgan, 2021). Therefore, optimizing storage conditions is essential to improve tomato shelf life.

The objective of this experiment was to evaluate the efficacy of chemical and biological products in controlling foliar pathogens in tomato crops grown in greenhouses, as well as to assess their effects on fruit quality and shelf life.

MATERIALS AND METHODS

The experience was conducted in two greenhouses at the Research Development Institute for Vegetable and Flower Growing Vidra, in 2024. Planting was made on 10 July, using tomato (*Solanum lycopersicum*) variety 'Prekos F1', arranged according to the method of randomized blocks, 4 replications. The treatements were applied preventively for *Alternaria solani* and *Fulvia fulva* and *Botrytis cinerea* control.

In the conventional system were made 2 applications to control the pathogens *A. solani* and *F. fulva* (July 19, 26) and 1 treatment for *B. cinerea* (September 6).

The experiment for conventional pathogen control consists on 4 variants treated and untreated control.

Conv. 1: Ortiva Top (azoxistrobin 200 g/L + difenoconazol 125 g/l) 1 l/ha (produced by Syngenta Crop Protection AG, Switzerland);

Conv. 2: Cidely Top (difenoconazol 125 g/l + ciflufenamid 15 g/l) 1 l/ha; Botrefin (cyprodinil 375 g/l + fludioxonil 250 g/l) 0.8 kg/ha (produced by Syngenta Crop Protection AG, Switzerland);

Conv. 3: Amistar (azoxistrobin 250 g/L) 0.75 l/ha; Sygnum (boscalid 26,7% + piraclostrobin 6,7%) 1.5 kg/ha (produced by Syngenta Crop Protection AG, Switzerland);

Conv. 4: Dagonis (difenoconazol 50 g/l + fluxapiroxad 75 g/l) 1 l/ha; Switch (fludioxonil 25% + ciprodinil 37,5%) 0.8 kg/ha (produced by BASF Agr B.V., Arnhem (NL) - Freienbach Branch, Switzerland);

Conv. 5: Untreated control.

Also, in the ecological pathogen control, the experience also includes 5 experimental variants, to which 6 treatments were applied: July 19 (T1), July 26 (T2), August 2 (T3), September 7 (T4), September 14 (T5) and September 21 (T6), as follows:

Biol. 1: Cavaler 600SL (microorganisms *Bacillus pumillus* and *Bacillus subtilis*) 0.3% (produced by Chromosome Dnamics S.A. Bucharest, Romania);

Biol. 2: Amulet (microorganisms *Bacillus thuringiensis, Bacillus subtilis, Bacillus megatherium*) 40 l/ha (produced in the U.E.);

Biol. 3: Zytron (citrus seed extract 20%) 0.15% (produced by Atlantica Agricola S.A. Spain);

Biol. 4: Mimoten (*Mimosa tenuifolia* 80% extract) 0.3% (produced by Atlantica Agricola S.A. Spain);

Biol. 5: Untreated control.

Observations and determinations were made on the leaves (5 plants/variant) regarding the frequency and severity of the *Alternaria solani*, *Fulvia fulva* and *Botrytis cinerea* pathogens, based on which the effectiveness of the products was calculated.

Climate data monitoring in greenhouse was done with the help of thermohygrometers, which record air temperature and humidity at hourly intervals.

The atmospheric humidity in the greenhouse was greatly influenced by the amount of precipitation that fell during this period. Thus, the precipitation that fell on July 17, 20 and 21, in the form of torrential rains, in amounts of 11, 18 and 22 l/sqm, caused an increase in atmospheric humidity to values of over 88%, between July 17 and 29.

In September, atmospheric humidity began to increase, with values between 85 and 92.4%

recorded in 19 days, with a maximum average of 84.1% for the month (Figure 1).
Tomato harvesting took place in Phase VI, according to the USDA tomato ripening stages (Bertin, 2018). The fruits were stored at temperatures of 6°C and 22°C, with a relative humidity of 70%.

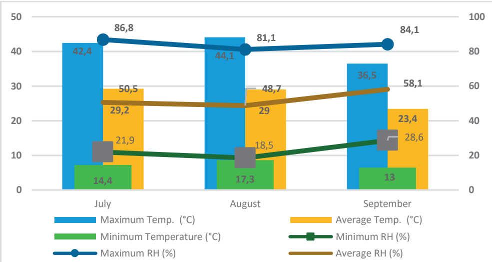

Figure 1. Greenhouse climate data
for the period July - september 2024

Fruit quality characteristics were evaluated at harvest and after 3, 5, 7, and 10 days of storage. The analyses included weight loss, dry weight, total soluble solids, firmness, pH and ash content. The percentage of weight loss was calculated based on the duration of storage, following the methodology presented by Tefera et al. (2007). The formula used was: Weight loss (%) = M_0 (M_0-M_1) × 100, where M_0 represents the initial mass of the fruits (g) and M_1 represents the mass of the fruits after storage (g).
Total dry matter content (DW), expressed as a percentage (%), was determined gravimetrically by heating at 105°C to constant weight (Krełowska-Kułas, 1993).
Total soluble solids (TSS) were measured by extracting tomato juice from 5 tomatoes per group using a food blender, followed by filtration. TSS was measured using a portable digital refractometer (Model: HI 96800, Hanna Instruments, USA), with the results expressed as % Brix (PN-90/A-75101/04. 1990).
Fruit firmness was assessed at four equidistant points along each tomato using a Force Gauge PCE-FM 200 firmness measuring instrument. The results obtained were expressed in Newtons (N) and averaged over a sample of ten fruits (n = 10).
The pH of each juice sample was measured using an electronic pH meter (Model: EUTECH Cyberscan pH 11, Singapore) equipped with a glass electrode. Ash content was determined by calcining the samples at 450°C and expressed as a percentage of fresh weight (% FW) (Horwitz, 2000).

Statistical analysis

All data were analyzed using SPSS 26.0 (International Business Machines Corp., Chicago, IL, USA). Results are presented as mean ± standard deviation (S.D.). A three-way analysis of variance (ANOVA) was performed to evaluate the effects of the independent variables-genetic background, storage condition and duration-on the dependent variables (chemical and physical parameters), at a significance level of 5% ($P < 0.05$).

RESULTS AND DISCUSSIONS

In conventional system, very good results in controling the pathogen *Alternaria solani* were obtained in all treated variants (Figure 2). The products Ortiva Top 1 l/ha, Cidely Top 1 l/ha, Amistar 0.75 l/ha and Dagonis 1 l/ha ensured an efficacy between 96.85% and 98.39% in controling this pathogen on leaves. The same products were also more than 99% efficacy in controlling the pathogen *Fulvia fulva* (Figure 2).
In the specialized literature, it is mentioned that fungicides containing difenoconazole and azoxystrobin (such as Score 25% SC and Amistar 25% SC) significantly reduce the incidence and severity of early blight disease in tomatoes, subsequently contributing to increasing the yield of tomato fruits (Ramadan et al., 2021). Strobilurin compounds, used as fungicides are very effective for a number of fungi including early blight (Bartlett et al., 2002; Pasche et al., 2004; Zafar and Shaukat, 2018). Strobilurins (azoxystrobin, pyraclostrobin and boscalid) are fungicides with beneficial physiological effects on crop yield due to promotion of net carbon assimilation, nitrate reductase enzyme activity, stress tolerance and hormonal balance (Esteves et al., 2018).
Azoxystrobin are known to break down this resistance because of their different mode of action as compared to other fungicides. Excellent control, curative, translaminar and systemic properties of azoxystrobin enables it to be used efficiently against leaf blight of tomato at very low application rates (Hewitt, 1998; Mejia Arreaza and Hernandez, 2001; Anand et al., 2010). Azoxystrobin shows a unique spectrum of disease control and is active against

Oomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes (Anand et al., 2010).
The atmospheric humidity in the greenhouse over 88%, between July 17 and 29, creates favorable conditions for the evolution of the pathogens *Alternaria solani* and *Fulvia fulva*.
In the biological control of the pathogen *Alternaria solani*, good results were obtained with the treated variants, with an efficacy between 58.79% (Amulet) and 66.30% (Mimoten) in controling this pathogen on leaves, and 66.67% (Cavaler 600SL) and 70% (Amulet, Zytron) on fruits. Also, low efficacy was recorded in the control of the pathogen *Fulvia fulva* with values between 44.05% (Amulet) and 54.54% (Cavaler 600SL).

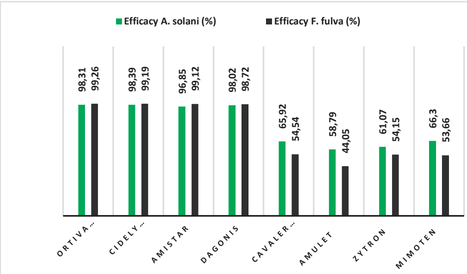

Figure 2. The efficacy of conventional and biological products on *A.solani* and *F. fulva*

The products Ortiva Top 1 l/ha, Botrefin 0.8 l/ha, Sygnum 1.5 kg/ha and Switch 0.8 l/ha, used to control gray rot, produced by the pathogen *Botrytis cinerea*, had a very good efficacy, between 97.89 and 98.67%. Among the treated variants, *Botrytis cinerea* attack was manifested on the fruits only in the variant treated with the product Ortiva Top 1 l/ha (Figure 3).
The efficacy of biological products was between 43.61% (Zytron) and 56.53% (Cavaler 600SL) in controlling the pathogen *Botrytis cinerea* on leaves and 63.10% (Amulet) – 70.23% (Zytron) on tomato fruits.
Specific strains of various *Bacillus* species have proven effective in controlling fungal pathogens, including *Fusarium, Rhizoctonia, Oidium, Septoria, Macrophomina, Botrytis, Pythium, Verticillium, Phytophthora, Sclerotium*, and *Alternaria*. *Bacillus* species possess the capability to decrease populations of fungal pathogens through the production of a substantial quantity of antibiotics (Iqbal et al., 2023).
Bacillus subtilis is one of the most potential biological control agents, because of the broad-spectrum activity of their antibiotics. Foliar application of *B. subtilis* alone and in combination with the plant nutrients managed early blight disease significantly (Awan & Shoaib, 2019).

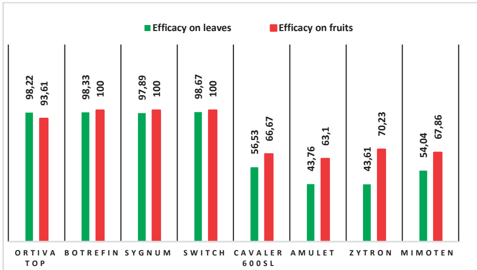

Figure 3. The efficacy of conventional and biological products on *B. cinerea*

In all variants treated with different protection products for *Alternaria solani*, *Fulvia fulva* and *Botrytis cinerea* pathogens control, yield increases with values between 7.33 and 9.01 t/ha for conventional and between 2.14 and 3.04 t/ha for biological (Figure 4).

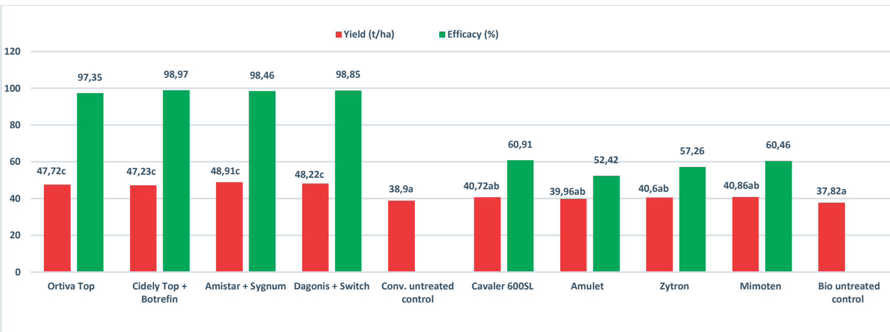

Figure 4. The influence of conventional and biological products on the yield of tomatoes grown in greenhouses

Results on quality maintenance during storage

Weight loss

In general, weight loss increases as the storage period is prolonged, suggesting a progressive degradation of product quality. Studies conducted over 10 days have revealed a significant decrease in tomato weight, attributable to respiration and transpiration processes (Anyasi et al., 2016; Moneruzzaman et al., 2008; Vunnam et al., 2014). At a temperature of 22°C, weight losses are significantly higher compared to those at 6°C, indicating that higher temperatures favor deterioration.

Weight loss also varies depending on the phytosanitary treatments applied during the growing season. For conventional products, losses ranged from 3.08% (Dagonis, Switch) to 3.59% (Amistar, Sygnum) with a control loss of 4.21% at 6°C, and from 4.40% (Ortiva Top) to 5.98% (Cidely Top, Btrefin) with a control loss of 6.91% at 22°C (Table 1). In the case of organic treatments, losses were between 2.31% (Zytron) and 4.31% (Mimoten) at 6°C and between 5.36% (Cavaler 600L) and 6.81% (Mimoten) at 22°C (Table 2). ANOVA analysis showed a significant influence of phytosanitary treatments on weight loss, with an impact of 62.0%.

The percentage of weight loss during storage is influenced by the stage of maturity of the product (Moneruzzaman et al., 2009). In general, fruits and vegetables are considered unmarketable if they lose between 5% and 10% of their initial weight, a phenomenon associated with quality deterioration, including wilting and shriveling (Ben-Yehoshua & Rodov, 2002). Excessive water loss not only reduces weight but also affects the texture and flavor of the products (Ben-Yehoshua & Rodov, 2002; Caleb et al., 2012). Water loss accelerates senescence and membrane degradation (Ben-Yehoshua et al., 1983). Additionally, factors such as pre-harvest conditions (including product type and orchard practices), harvest parameters (such as injuries and damages, maturity stage, weather conditions, harvesting method, and crown position), and post-harvest management (covering storage conditions and pre-treatments) significantly influence water loss (Tyagi et al., 2017; Lufu et al., 2020).

Dry weight content

Tomatoes contain between 92.5% and 95% water, with the remaining 5% to 7.5% consisting of total dry weight (Davies & Hobson, 1981). The composition of the dry weight includes sugars, particularly carbohydrates such as glucose and fructose, which constitute approximately 48% of the total sugars, as well as lipids, proteins, minerals, vitamins, organic acids, and phenolic compounds (Kader, 2002). The dry weight of tomatoes can be influenced by various factors, including genotype, environmental conditions, cultivation methods, and the amount of water used in irrigation. Water loss and the total dry weight remaining were not affected by the phytosanitary protection treatments applied during the growing season. However, storage temperature and storage time had a significant impact on dry weight, accounting for 14.1% and 66.8% of the variation, respectively, according to ANOVA analysis. The highest values of this biochemical indicator were observed after 10 days of storage at ambient temperature - 6.55% for conventional treatments, 6.85% for organic treatments, and 7.02% for the control. These values were similar to the observed weight losses of 4.95%, 6.03%, and 6.96%, respectively (Table 3).

Total soluble solids content

Regarding the total soluble solids (TSS) content, no variations were observed during cold storage or at ambient temperature, depending on the type of phytosanitary treatments applied during the growing period. Instead, a progressive increase in TSS was noted over the storage duration. The average soluble solids content of tomatoes varied between 4.27°Brix (Dagonis, Switch) and 4.31°Brix (Cidely Top, Botrefin) at harvest (conventional variant) and increased to between 5.20° Brix (Ortiva Top) and 5.47° Brix (Amistar, Sygnum) at 6°C. At 22°C, TSS varied between 6.12° Brix (Ortiva Top) and 6.78°Brix (Dagonis, Switch). The organic variant recorded higher TSS values, reaching a maximum of 5.84°Brix (Amulet) at 6°C and 6.54°Brix (Amulet) at 22°C. From the perspective of Duncan's test, TSS was significantly influenced only by storage temperature and storage time. Similar results were obtained by Al-Dairi et al. (2021). Islam et al. (2012) noted an increase in TSS in tomatoes during storage, rising from 4.20% to 5.00% after 7 days at room temperature. They also observed a variation from 4.10% to 4.90% in tomatoes stored under low-temperature conditions after 17 days of storage. Rab et al. (2013) reported that, in the case of tomatoes not subjected to pre-cooling, the average TSS content reached 8.66%.

Firmness

Tomato firmness is a fundamental criterion in the marketing process. Statistical analysis revealed a decrease in fruit firmness during the ten days of storage. At the beginning of this period, the average firmness of tomatoes treated with conventional phytosanitary products ranged from approximately 15.44 N (Dagonis, Switch) to 16.73 N (Amistar, Sygnum).

Table 1. Characteristics of 'Prekos F1' hybrid tomato treated with conventional phytosanitary products during storage: weight loss (%), dry weight (%), total soluble solids (TSS, °Brix), firmness (N), pH and ash (%)

Storage temperature	Storage time (days)	Variant	Weight loss (%)	Dry weight (%)	TSS (°Brix)	Firmness (N)	pH	Ash (%)
6°C	At harvest	Conv. 1	-	5.97 ± 0.29^{a}	4.30 ± 0.17^{a}	16.22 ± 1.35^{a}	3.97 ± 0.18^{a}	0.44 ± 0.01^{a}
		Conv. 2	-	4.60 ± 0.28^{c}	4.31 ± 0.08^{a}	15.76 ± 1.69^{a}	4.02 ± 0.11^{a}	0.44 ± 0.01^{a}
		Conv. 3	-	5.61 ± 0.08^{b}	4.28 ± 0.23^{a}	16.73 ± 1.12^{a}	4.04 ± 0.09^{a}	0.43 ± 0.01^{a}
		Conv. 4	-	4.91 ± 0.09^{c}	4.27 ± 0.42^{a}	15.44 ± 0.98^{a}	4.00 ± 0.11^{a}	0.43 ± 0.03^{a}
		Conv. 5	-	4.75 ± 0.01^{c}	4.23 ± 0.32^{a}	15.45 ± 1.32^{a}	4.02 ± 0.47^{a}	0.44 ± 0.01^{a}
	3 days	Conv. 1	0.69 ± 0.28^{a}	5.75 ± 0.26^{a}	4.41 ± 0.19^{a}	15.52 ± 1.67^{a}	4.00 ± 0.21^{a}	0.44 ± 0.01^{ab}
		Conv. 2	0.88 ± 0.31^{a}	6.11 ± 0.47^{a}	4.37 ± 0.15^{a}	15.24 ± 1.66^{a}	4.05 ± 0.19^{a}	0.46 ± 0.01^{a}
		Conv. 3	0.67 ± 0.44^{a}	5.15 ± 0.14^{b}	4.47 ± 0.26^{a}	16.11 ± 2.09^{a}	4.09 ± 0.14^{a}	0.43 ± 0.01^{b}
		Conv. 4	0.79 ± 0.69^{a}	5.61 ± 0.84^{ab}	4.59 ± 0.44^{a}	14.79 ± 1.96^{b}	4.03 ± 0.21^{a}	0.44 ± 0.01^{ab}
		Conv. 5	1.07 ± 0.35^{a}	5.27 ± 0.32^{b}	4.40 ± 0.62^{a}	13.68 ± 2.00^{b}	4.07 ± 0.38^{a}	0.45 ± 0.01^{ab}
	5 days	Conv. 1	1.50 ± 0.49^{b}	6.14 ± 0.20^{ab}	4.62 ± 0.22^{a}	14.44 ± 1.96^{a}	4.08 ± 0.27^{a}	0.45 ± 0.01^{ab}
		Conv. 2	1.62 ± 0.38^{b}	6.34 ± 0.30^{ab}	4.62 ± 0.35^{a}	14.11 ± 1.60^{a}	4.11 ± 0.32^{a}	0.48 ± 0.04^{ab}
		Conv. 3	1.23 ± 0.33^{c}	5.33 ± 0.17^{c}	4.57 ± 0.29^{a}	15.02 ± 1.75^{a}	4.11 ± 0.18^{a}	0.43 ± 0.01^{b}
		Conv. 4	1.42 ± 0.71^{bc}	5.81 ± 0.28^{b}	4.65 ± 0.45^{a}	12.00 ± 2.85^{b}	4.07 ± 0.22^{a}	0.46 ± 0.01^{ab}
		Conv. 5	2.63 ± 0.61^{a}	5.86 ± 0.12^{b}	4.47 ± 0.38^{a}	12.08 ± 1.33^{b}	4.10 ± 0.27^{a}	0.49 ± 0.02^{a}
	7 days	Conv. 1	2.01 ± 0.56^{b}	6.21 ± 0.13^{ab}	5.13 ± 0.91^{a}	12.97 ± 1.11^{a}	4.12 ± 0.14^{a}	0.46 ± 0.01^{bc}
		Conv. 2	2.25 ± 0.23^{b}	6.35 ± 0.42^{a}	5.23 ± 0.21^{a}	12.44 ± 1.32^{a}	4.15 ± 0.37^{a}	0.49 ± 0.02^{a}
		Conv. 3	2.28 ± 0.66^{b}	6.41 ± 0.29^{a}	5.10 ± 0.75^{a}	13.00 ± 1.21^{a}	4.14 ± 0.25^{a}	0.46 ± 0.02^{c}
		Conv. 4	1.97 ± 0.57^{b}	5.95 ± 0.21^{b}	4.95 ± 0.40^{a}	11.08 ± 0.97^{b}	4.17 ± 0.37^{a}	0.49 ± 0.01^{ab}
		Conv. 5	3.12 ± 0.56^{a}	6.08 ± 0.06^{b}	5.05 ± 0.64^{a}	11.07 ± 1.14^{b}	4.19 ± 0.22^{a}	0.51 ± 0.01^{a}
	10 days	Conv. 1	3.15 ± 0.97^{b}	6.45 ± 0.38^{a}	5.28 ± 0.75^{a}	10.41 ± 0.85^{a}	4.18 ± 0.20^{a}	0.47 ± 0.01^{c}
		Conv. 2	3.27 ± 0.35^{b}	6.54 ± 0.23^{a}	5.33 ± 0.55^{a}	10.11 ± 1.33^{a}	4.21 ± 0.19^{a}	0.56 ± 0.02^{a}
		Conv. 3	3.59 ± 1.31^{ab}	6.56 ± 0.24^{a}	5.47 ± 0.34^{a}	10.63 ± 1.40^{a}	4.19 ± 0.24^{a}	0.50 ± 0.02^{bc}
		Conv. 4	3.08 ± 0.93^{b}	6.44 ± 0.45^{a}	5.38 ± 0.42^{a}	9.77 ± 1.35^{b}	4.22 ± 0.24^{a}	0.51 ± 0.01^{b}
		Conv. 5	4.21 ± 0.86^{a}	6.32 ± 0.33^{a}	5.25 ± 0.27^{a}	9.81 ± 0.99^{b}	4.27 ± 0.40^{a}	0.53 ± 0.01^{b}
22°C	At harvest	Conv. 1	-	5.81 ± 0.31^{a}	4.28 ± 0.15^{a}	16.19 ± 1.31^{a}	4.00 ± 0.15^{a}	0.46 ± 0.01^{a}
		Conv. 2	-	4.63 ± 0.35^{a}	4.34 ± 0.28^{a}	15.78 ± 1.75^{a}	4.03 ± 0.20^{a}	0.44 ± 0.02^{b}
		Conv. 3	-	5.57 ± 1.60^{a}	4.27 ± 0.19^{a}	16.70 ± 1.48^{a}	4.04 ± 0.11^{a}	0.44 ± 0.01^{b}
		Conv. 4	-	4.88 ± 0.26^{a}	4.24 ± 0.32^{a}	15.45 ± 0.93^{a}	4.05 ± 0.09^{a}	0.43 ± 0.01^{b}
		Conv. 5	-	5.78 ± 0.45^{a}	4.22 ± 0.40^{a}	15.46 ± 1.47^{a}	4.06 ± 0.26^{a}	0.49 ± 0.00^{a}
	3 days	Conv. 1	1.53 ± 0.37^{b}	5.84 ± 0.46^{b}	5.29 ± 0.73^{a}	14.97 ± 1.82^{a}	4.08 ± 0.44^{a}	0.48 ± 0.01^{a}
		Conv. 2	1.72 ± 0.27^{b}	5.95 ± 0.18^{a}	5.64 ± 0.43^{a}	13.85 ± 1.42^{a}	4.11 ± 0.17^{a}	0.46 ± 0.01^{b}
		Conv. 3	1.62 ± 0.36^{b}	5.85 ± 0.04^{ab}	5.10 ± 0.75^{a}	14.01 ± 1.73^{a}	4.11 ± 0.20^{a}	0.46 ± 0.01^{b}
		Conv. 4	2.86 ± 1.18^{a}	6.10 ± 0.31^{a}	4.95 ± 0.80^{a}	11.98 ± 1.55^{b}	4.17 ± 0.23^{a}	0.43 ± 0.01^{c}
		Conv. 5	3.12 ± 1.52^{a}	6.19 ± 0.10^{a}	4.72 ± 0.64^{a}	11.26 ± 2.03^{b}	4.16 ± 0.31^{a}	0.45 ± 0.01^{bc}
	5 days	Conv. 1	2.11 ± 0.18^{b}	6.05 ± 0.24^{a}	5.55 ± 0.61^{a}	12.02 ± 1.35^{a}	4.15 ± 0.19^{a}	0.51 ± 0.01^{a}
		Conv. 2	2.56 ± 0.28^{b}	6.33 ± 0.47^{a}	5.71 ± 0.44^{a}	11.01 ± 1.17^{a}	4.19 ± 0.27^{a}	0.47 ± 0.02^{ab}
		Conv. 3	2.44 ± 1.22^{b}	6.27 ± 0.07^{a}	5.37 ± 0.21^{a}	12.31 ± 1.15^{a}	4.16 ± 0.22^{a}	0.47 ± 0.02^{ab}
		Conv. 4	2.63 ± 1.55^{b}	6.54 ± 0.41^{a}	5.63 ± 0.54^{a}	9.96 ± 1.36^{b}	4.23 ± 0.31^{a}	0.44 ± 0.02^{b}
		Conv. 5	3.81 ± 0.76^{a}	6.26 ± 0.34^{a}	5.27 ± 0.77^{a}	9.78 ± 1.41^{b}	4.35 ± 0.25^{a}	0.47 ± 0.03^{ab}
	7 days	Conv. 1	3.12 ± 0.85^{b}	6.37 ± 0.32^{a}	5.72 ± 0.59^{a}	11.17 ± 1.22^{a}	4.28 ± 0.18^{a}	0.52 ± 0.02^{a}
		Conv. 2	4.40 ± 1.24^{a}	6.66 ± 0.28^{a}	5.94 ± 0.63^{a}	11.05 ± 1.16^{ab}	4.32 ± 0.29^{a}	0.49 ± 0.01^{ab}
		Conv. 3	2.82 ± 1.22^{b}	6.26 ± 0.19^{a}	5.62 ± 0.31^{a}	12.11 ± 1.37^{a}	4.27 ± 0.28^{a}	0.47 ± 0.02^{b}
		Conv. 4	3.31 ± 1.48^{b}	6.56 ± 0.16^{a}	6.31 ± 0.45^{a}	9.08 ± 0.83^{b}	4.37 ± 0.41^{a}	0.47 ± 0.02^{b}
		Conv. 5	5.18 ± 1.88^{a}	6.97 ± 0.24^{a}	5.55 ± 0.37^{a}	9.14 ± 1.26^{b}	4.40 ± 0.34^{a}	0.50 ± 0.02^{ab}
	10 days	Conv. 1	4.40 ± 1.58^{b}	6.63 ± 0.27^{a}	6.12 ± 0.47^{a}	8.32 ± 1.15^{a}	4.36 ± 0.27^{a}	0.54 ± 0.04^{a}
		Conv. 2	5.98 ± 1.26^{a}	6.94 ± 0.22^{a}	6.24 ± 0.58^{a}	8.24 ± 1.40^{a}	4.39 ± 0.33^{a}	0.58 ± 0.08^{a}
		Conv. 3	4.72 ± 1.41^{b}	6.93 ± 0.18^{a}	6.24 ± 0.44^{a}	8.00 ± 1.15^{a}	4.37 ± 0.25^{a}	0.52 ± 0.01^{a}
		Conv. 4	4.69 ± 1.57^{b}	6.88 ± 0.14^{a}	6.78 ± 0.55^{a}	7.28 ± 0.87^{b}	4.48 ± 0.47^{a}	0.51 ± 0.05^{a}
		Conv. 5	6.91 ± 1.00^{a}	7.05 ± 0.44^{a}	6.07 ± 0.29^{a}	7.44 ± 0.93^{b}	4.56 ± 0.41^{a}	0.57 ± 0.01^{a}

*Duncan test: Mean values in a column that do not share the same letter (a, b, c) indicate significant differences ($p \leq 0.05$).

Table 2. Characteristics of 'Prekos F1' hybrid tomato treated with organic phytosanitary products during storage: weight loss (%), dry weight (%), total soluble solids (TSS, °Brix), firmness (N), pH and ash content (%)

Storage temperature	Storage time (days)	Variant	Weight loss (%)	Dry weight. (%)	TSS (°Brix)	Firmness (N)	pH	Ash (%)
6°C	At harvest	Biol. 1	-	5.19±0.29^{a}	4.47±0.23^{a}	16.26±1.40^{a}	3.89±0.24^{a}	0.45±0.01^{a}
		Biol. 2	-	4.93±0.28^{a}	4.55±0.17^{a}	15.79±1.24^{a}	3.95±0.08^{a}	0.46±0.01^{a}
		Biol. 3	-	5.05±0.08^{a}	4.39±0.31^{a}	16.65±1.38^{a}	4.03±0.16^{a}	0.43±0.01^{a}
		Biol. 4	-	4.90±0.09^{a}	4.26±0.12^{a}	15.51±1.15^{a}	4.02±0.22^{a}	0.43±0.03^{a}
		Biol. 5	-	4.76±0.01^{a}	4.25±0.44^{a}	15.44±0.99^{a}	4.02±0.33^{a}	0.44±0.01^{a}
	3 days	Biol. 1	0.91±0.18^{a}	5.22±0.46^{a}	4.93±0.45^{a}	15.64±1.23^{a}	3.99±0.23^{a}	0.48±0.01^{a}
		Biol. 2	0.75±0.09^{a}	5.07±0.15^{a}	5.05±0.17^{a}	15.38±1.35^{a}	4.04±0.20^{a}	0.47±0.01^{a}
		Biol. 3	0.72±0.20^{a}	5.08±0.28^{a}	4.82±0.31^{a}	16.20±2.04^{a}	4.07±0.18^{a}	0.45±0.01^{b}
		Biol. 4	1.30±0.47^{a}	5.40±0.81^{a}	4.75±0.12^{a}	13.88±1.42^{b}	4.08±0.28^{a}	0.44±0.01^{b}
		Biol. 5	1.08±0.35^{a}	5.27±0.33^{a}	4.41±0.44^{a}	13.65±1.58^{b}	4.06±0.35^{a}	0.45±0.01^{b}
	5 days	Biol. 1	1.74±0.62^{ab}	5.47±0.32^{a}	5.43±0.31^{a}	14.50±1.77^{a}	4.07±0.31^{a}	0.50±0.01^{a}
		Biol. 2	1.69±0.51^{ab}	5.38±0.48^{a}	5.10±0.10^{a}	14.18±1.81^{a}	4.09±0.32^{a}	0.49±0.03^{a}
		Biol. 3	1.19±0.55^{b}	5.22±0.37^{a}	5.40±0.17^{a}	14.91±1.28^{a}	4.11±0.25^{a}	0.46±0.01^{b}
		Biol. 4	2.58±0.83^{a}	5.75±0.40^{a}	5.00±0.54^{a}	12.15±2.43^{b}	4.09±0.22^{a}	0.44±0.01^{b}
		Biol. 5	2.62±0.76^{a}	5.86±0.48^{a}	4.50±0.73^{a}	12.10±1.38^{b}	4.09±0.19^{a}	0.48±0.02^{a}
	7 days	Biol. 1	2.23±0.49^{b}	5.59±0.09^{b}	5.48±0.53^{a}	13.12±1.55^{a}	4.11±0.38^{a}	0.50±0.03^{ab}
		Biol. 2	2.25±0.50^{b}	5.60±0.25^{b}	5.46±0.19^{a}	12.62±1.17^{a}	4.14±0.26^{a}	0.50±0.01^{ab}
		Biol. 3	1.69±0.46^{c}	5.47±0.25^{b}	5.42±0.25^{a}	13.09±1.31^{a}	4.17±0.31^{a}	0.48±0.02^{b}
		Biol. 4	3.04±0.75^{a}	6.01±0.11^{a}	5.51±0.68^{a}	11.21±0.83^{b}	4.17±0.35^{a}	0.51±0.01^{a}
		Biol. 5	3.13±0.82^{a}	6.07±0.44^{a}	5.07±0.49^{a}	11.05±1.29^{b}	4.20±0.29^{a}	0.51±0.02^{a}
	10 days	Biol. 1	2.96±0.50^{b}	5.88±0.34^{b}	5.61±0.38^{a}	10.30±1.14^{a}	4.16±0.20^{a}	0.51±0.01^{b}
		Biol. 2	3.44±0.76^{b}	6.20±0.27^{a}	5.84±0.26^{a}	10.06±1.27^{a}	4.19±0.19^{a}	0.50±0.03^{b}
		Biol. 3	2.31±0.82^{c}	5.60±0.46^{b}	5.50±0.18^{a}	10.21±1.34^{a}	4.23±0.25^{a}	0.53±0.02^{a}
		Biol. 4	4.31±0.59^{a}	6.22±0.28^{a}	5.67±0.47^{a}	9.44±1.08^{b}	4.23±0.37^{a}	0.53±0.03^{a}
		Biol. 5	4.20±0.41^{a}	6.31±0.30^{a}	5.25±0.60^{a}	9.80±0.86^{b}	4.26±0.40^{a}	0.54±0.04^{a}
22°C	At harvest	Biol. 1	-	5.17±0.46^{a}	4.44±0.31^{a}	16.21±1.16^{a}	3.90±0.18^{a}	0.46±0.01^{a}
		Biol. 2	-	5.89±0.35^{a}	4.58±0.23^{a}	15.73±1.81^{a}	3.94±0.32^{a}	0.45±0.02^{a}
		Biol. 3	-	5.07±1.60^{a}	4.42±0.15^{a}	16.67±1.55^{a}	4.05±0.29^{a}	0.44±0.01^{b}
		Biol. 4	-	4.94±0.26^{a}	4.22±0.25^{a}	15.46±0.99^{b}	4.01±0.17^{a}	0.44±0.01^{b}
		Biol. 5	-	4.80±0.45^{a}	4.21±0.39^{a}	15.46±1.38^{b}	4.04±0.22^{a}	0.43±0.02^{b}
	3 days	Biol. 1	1.52±0.34^{b}	5.97±0.19^{a}	5.08±0.51^{a}	15.01±1.77^{a}	4.07±0.19^{a}	0.50±0.03^{a}
		Biol. 2	1.37±0.24^{b}	5.90±0.08^{a}	5.17±0.32^{a}	13.88±1.56^{a}	4.14±0.28^{a}	0.46±0.01^{b}
		Biol. 3	1.70±0.55^{b}	6.03±0.32^{a}	5.02±0.46^{a}	14.22±1.47^{a}	4.11±0.31^{a}	0.49±0.01^{a}
		Biol. 4	2.59±0.14^{a}	6.14±0.19^{a}	4.67±0.27^{a}	12.08±1.33^{b}	4.22±0.27^{a}	0.45±0.02^{b}
		Biol. 5	3.12±0.65^{a}	6.21±0.35^{a}	4.71±0.28^{a}	11.27±1.88^{b}	4.17±0.33^{a}	0.45±0.02^{b}
	5 days	Biol. 1	2.25±0.42^{b}	5.98±0.21^{a}	5.39±0.27^{a}	11.97±1.28^{a}	4.22±0.44^{a}	0.50±0.02^{a}
		Biol. 2	2.33±0.43^{b}	6.01±0.09^{a}	5.77±0.22^{a}	10.63±1.03^{a}	4.19±0.27^{a}	0.48±0.03^{b}
		Biol. 3	2.49±0.40^{b}	6.17±0.28^{a}	5.62±0.45^{a}	11.58±1.03^{a}	4.27±0.38^{a}	0.50±0.02^{a}
		Biol. 4	2.95±0.44^{ab}	6.21±0.31^{a}	5,02±0.50^{a}	9.68±1.21^{b}	4.24±0.25^{a}	0.47±0.02^{b}
		Biol. 5	3.82±0.92^{a}	6.24±0.31^{a}	5.30±0.44^{a}	9.77±1.29^{b}	4.33±0.37^{a}	0.47±0.02^{b}
	7 days	Biol. 1	2.83±0.97^{c}	6.05±0.38^{a}	5.56±0.33^{a}	10.20±1.51^{a}	4.34±0.29^{a}	0.51±0.01^{a}
		Biol. 2	4.27±1.12^{b}	6.38±0.44^{a}	5.92±0.18^{a}	10.47±1.17^{ab}	4.40±0.34^{a}	0.50±0.02^{a}
		Biol. 3	4.33±0.40^{b}	6.47±0.22^{a}	6.08±0.29^{a}	10.18±1.22^{a}	4.35±0.22^{a}	0.52±0.02^{a}
		Biol. 4	5.83±0.78^{a}	6.62±0.33^{a}	6.12±0.41^{a}	9.35±0.68^{b}	4.41±0.36^{a}	0.52±0.03^{a}
		Biol. 5	5.19±1.19^{a}	6.55±0.18^{a}	5.58±0.46^{a}	9.12±1.04^{b}	4.40±0.35^{a}	0.51±0.01^{a}
	10 days	Biol. 1	5.36±0.75^{b}	6.11±0.25^{b}	5.88±0.20^{a}	7.51±1.18^{a}	4.47±0.36^{a}	0.54±0.02^{b}
		Biol. 2	6.37±1.62^{a}	6.67±0.27^{a}	6.54±0.32^{a}	7.37±1.33^{a}	4.44±0.28^{a}	0.55±0.01^{b}
		Biol. 3	5.57±0.90^{ab}	6.53±0.22^{ab}	6.22±0.17^{a}	7.22±1.21^{a}	4.50±0.37^{a}	0.58±0.06^{a}
		Biol. 4	6.81±1.08^{a}	6.88±0.35^{a}	6.43±0.28^{a}	6.89±0.74^{b}	4.57±0.44^{a}	0.59±0.03^{a}
		Biol. 5	6.90±1.74^{a}	6.99±0.46^{a}	6.10±0.31^{a}	7.42±1.15^{b}	4.55±0.33^{a}	0.58±0.04^{a}

*Duncan test: Mean values in a column that do not share the same letter (a, b, c) indicate significant differences ($p \leq 0.05$).

After ten days, this value decreased to a range of 7.28 N (Dagonis, Switch) to 8.32 N (Ortiva Top). In tomatoes treated with organic phytosanitary products, the average firmness at harvest was between 15.51 N (Mimoten) and 16.65 N (Zytron). After ten days of storage at 22°C, fruit firmness ranged from 6.89 N (Mimoten) to 7.51 N (Cavaler 600SL), which is lower than that of the conventional variety. Significant differences in fruit firmness were observed after five days of storage at 6°C and after three days at 22°C due to the phytosanitary treatments applied pre-harvest. These results suggest that pre-harvest agricultural management conditions can significantly influence tomato firmness during the post-harvest period. Paull et al. (1999) noted that during tomato fruit ripening, hemicelluloses and pectin become more soluble, leading to damage and weakening of the cell walls, which results in softer fruit. According to previous research, for tomatoes to maintain their commercial characteristics after the storage period, their firmness should not fall below 4-5 N (Kader, 2002).

Table 3. Comparison of the effects of phytosanitary protection methods on the quality of stored tomatoes at different temperatures

Storage temperature	Storage time (days)	Phytosanitary product	Weight loss (%)	Dry weight. (%)	TSS (% Brix)	Firmness (N)	pH	Ash (%)
6°C	At harvest	Conventional	-	5.27 ± 0.63^{a}	4.29 ± 0.02^{b}	15.80 ± 0.96^{a}	4.01 ± 0.03^{a}	0.44 ± 0.01^{a}
		Biological	-	5.02 ± 0.13^{a}	4.42 ± 0.12^{a}	15.80 ± 0.93^{a}	3.97 ± 0.07^{a}	0.43 ± 0.10^{a}
		Control	-	5.18 ± 0.48^{a}	4.24 ± 0.04^{b}	14.45 ± 0.04^{b}	4.03 ± 0.02^{a}	0.42 ± 0.02^{a}
	3 days	Conventional	0.76 ± 0.10^{b}	5.66 ± 0.39^{a}	4.46 ± 0.10^{b}	15.17 ± 0.99^{a}	4.04 ± 0.04^{a}	0.44 ± 0.01^{a}
		Biological	0.92 ± 0.27^{ab}	5.19 ± 0.15^{a}	4.89 ± 0.13^{a}	15.28 ± 0.99^{a}	4.05 ± 0.04^{a}	0.46 ± 0.02^{a}
		Control	1.13 ± 0.05^{a}	5.72 ± 0.49^{a}	4.84 ± 0.30^{a}	13.67 ± 0.06^{b}	4.07 ± 0.03^{a}	0.45 ± 0.01^{a}
	5 days	Conventional	1.44 ± 0.16^{b}	5.91 ± 0.44^{ab}	4.62 ± 0.03^{a}	13.89 ± 1.31^{a}	4.09 ± 0.08^{a}	0.46 ± 0.02^{b}
		Biological	1.80 ± 0.58^{b}	5.46 ± 0.22^{b}	5.23 ± 0.22^{a}	13.94 ± 1.22^{a}	4.09 ± 0.02^{a}	0.47 ± 0.03^{a}
		Control	2.63 ± 0.06^{a}	6.14 ± 0.30^{a}	4.84 ± 0.39^{a}	12.09 ± 0.08^{b}	4.08 ± 0.03^{a}	0.49 ± 0.01^{a}
	7 days	Conventional	2.13 ± 0.16^{b}	6.23 ± 0.20^{b}	5.10 ± 0.12^{b}	12.37 ± 0.90^{a}	$4.15\pm0.\ 02^{a}$	0.48 ± 0.02^{b}
		Biological	2.30 ± 0.56^{b}	5.67 ± 0.24^{a}	5.47 ± 0.04^{a}	12.51 ± 0.90^{a}	4.15 ± 0.03^{a}	0.50 ± 0.01^{a}
		Control	3.11 ± 0.03^{a}	6.31 ± 0.27^{a}	5.30 ± 0.30^{ab}	11.03 ± 0.12^{b}	4.20 ± 0.06^{a}	0.51 ± 0.01^{a}
	10 days	Conventional	3.27 ± 0.23^{b}	6.50 ± 0.16^{a}	5.37 ± 0.08^{b}	10.23 ± 0.37^{a}	4.20 ± 0.02^{a}	0.51 ± 0.04^{a}
		Biological	3.25 ± 0.85^{b}	4.43 ± 2.96^{a}	5.86 ± 0.14^{a}	10.45 ± 1.97^{a}	4.20 ± 0.03^{a}	0.52 ± 0.02^{a}
		Control	4.22 ± 0.38^{a}	6.50 ± 0.22^{a}	5.65 ± 0.12^{a}	9.81 ± 0.06^{b}	4.27 ± 0.06^{a}	0.53 ± 0.03^{a}
22°C	At harvest	Conventional	-	5.22 ± 0.56^{a}	$4.28v0.04^{b}$	15.78 ± 0.96^{a}	4.03 ± 0.02^{ab}	0.44 ± 0.01^{a}
		Biological	-	5.27 ± 0.43^{a}	4.42 ± 0.15^{a}	15.77 ± 0.95^{a}	3.98 ± 0.09^{b}	0.44 ± 0.03^{a}
		Control	-	5.23 ± 0.47^{a}	4.24 ± 0.05^{b}	14.48 ± 0.13^{b}	4.05 ± 0.05^{a}	0.44 ± 0.01^{a}
	3 days	Conventional	1.93 ± 0.62^{b}	5.94 ± 0.12^{b}	5.25 ± 0.30^{a}	13.70 ± 1.25^{a}	4.12 ± 0.04^{b}	0.46 ± 0.02^{a}
		Biological	1.80 ± 0.55^{b}	6.01 ± 0.10^{b}	4.99 ± 0.22^{ab}	13.80 ± 1.23^{a}	4.13 ± 0.05^{b}	0.48 ± 0.02^{a}
		Control	2.15 ± 0.10^{a}	6.20 ± 0.12^{a}	4.87 ± 0.18^{b}	11.27 ± 0.17^{b}	4.17 ± 0.04^{a}	0.45 ± 0.02^{a}
	5 days	Conventional	2.44 ± 0.23^{b}	6.30 ± 0.20^{b}	5.57 ± 0.15^{ab}	11.33 ± 1.07^{a}	4.17 ± 0.05^{b}	0.47 ± 0.03^{a}
		Biological	2.51 ± 0.31^{b}	6.39 ± 0.11^{ab}	5.45 ± 0.33^{b}	10.97 ± 1.02^{a}	4.23 ± 0.03^{b}	0.49 ± 0.02^{a}
		Control	3.80 ± 0.06^{a}	6.43 ± 0.24^{a}	5.82 ± 0.18^{a}	9.78 ± 0.18^{b}	4.34 ± 0.04^{a}	0.47 ± 0.01^{a}
	7 days	Conventional	3.41 ± 0.69^{b}	6.36 ± 0.18^{a}	5.90 ± 0.31^{a}	10.85 ± 1.27^{a}	4.31 ± 0.05^{b}	0.48 ± 0.02^{a}
		Biological	4.32 ± 1.22^{ab}	6.48 ± 0.24^{a}	5.92 ± 0.26^{a}	10.05 ± 0.49^{ab}	4.36 ± 0.05^{ab}	0.51 ± 0.01^{a}
		Control	5.16 ± 0.07^{a}	6.63 ± 0.17^{a}	6.12 ± 0.31^{a}	9.13 ± 0.09^{b}	4.40 ± 0.07^{a}	0.51 ± 0.02^{a}
	10 days	Conventional	4.95 ± 0.70^{c}	6.55 ± 0.15^{a}	6.35 ± 0.30^{a}	7.96 ± 0.47^{a}	4.40 ± 0.05^{b}	0.54 ± 0.03^{a}
		Biological	6.03 ± 0.68^{b}	6.85 ± 0.33^{b}	6.22 ± 0.24^{a}	7.24 ± 0.27^{b}	4.50 ± 0.06^{a}	0.57 ± 0.02^{a}
		Control	6.96 ± 0.11^{a}	7.02 ± 0.09^{a}	6.57 ± 0.23^{a}	7.43 ± 0.13^{b}	4.56 ± 0.05^{a}	0.58 ± 0.02^{a}
Total		Conventional	2.03 ± 1.55^{c}	6.15 ± 0.62^{a}	6.35 ± 0.30^{a}	12.71 ± 2.66^{a}	4.15 ± 0.12^{b}	0.47 ± 0.04^{a}
		Biological	2.29 ± 1.88^{b}	6.06 ± 0.51^{a}	6.21 ± 0.24^{a}	12.28 ± 1.48^{a}	4.17 ± 0.17^{b}	0.47 ± 0.09^{a}
		Control	3.02 ± 1.11^{a}	6.30 ± 0.86^{a}	6.57 ± 0.23^{a}	11.31 ± 2.26^{b}	4.21 ± 0.17^{a}	0.48 ± 0.08^{a}

*Duncan test: Mean values in a column that do not share the same letter (a, b, c) indicate significant differences ($p \leq 0.05$).

pH

Organic acids in fruits are derived from stored carbohydrates (Sakiyama & Stevens, 1976), although some may be transported from leaves and roots to the fruit (Davies & Maw, 1972). Tomatoes with high acid and sugar content are valued for their superior flavor, while those with low acidity are often considered tasteless (Etissa et al., 2014). The study did not reveal significant differences in the pH of fruits treated with various phytosanitary methods, whether organic or conventional. However, a slight trend towards an increase in organic acid content was noted, as indicated by lower pH values. The specialized literature mentions that phytosanitary treatments applied during tomato cultivation result in changes in cellular metabolism and variations in the production of secondary compounds, including acids (Kumar et al., 2021). The ripening process of fruits leads to a decrease in acidity, which is revealed by an increase in pH, a phenomenon that is more pronounced at ambient temperatures. Refrigeration helps maintain acidity. Previous studies suggest that fruit acidity decreases due to the utilization of acids as an energy source, a process through which they are converted into sugars (Karadeniz, 2004). Given that organic acids serve as substrates for respiration in enzymatic reactions, it is expected that total acidity will be lower in the post-harvest period (Shokrollahfam et al., 2012, cited by Zeraatgar et al., 2018).

Ash content

The ash content of foods reflects the total raw minerals present. The 'Prekos F1' hybrid exhibited an ash content of 0.43-0.46% at harvest, which aligns with the range reported by Agbemafle et al. (2015). Notably, the ash concentration was not influenced by the phytosanitary treatments applied; rather, it increased proportionally with the weight loss of the fruit. Specialized studies confirm that mineral concentrations in fruits typically remain constant during storage, except in cases of water loss or metabolic activity (Garuba et al., 2018).

The analysis of Table 3 highlights significant differences between conventional and organic (Eco) phytosanitary protection methods compared to the control group (without treatment) in terms of preserving fruit quality during storage. The organic method maintains superior tomato quality for up to 10 days, but only at a low temperature of 6°C, resulting in lower weight losses. In contrast, the conventional method effectively preserves tomato quality at ambient temperatures of 22°C for the same duration.

Table 4 presents the relationships among the studied indicators. The results revealed strong linear correlations, both positive and negative, particularly between storage time and various quality indicators. Significant correlations were observed with weight loss (r=0.849), firmness (r=-0.826), fruit pH (r=0.766), dry weight content (r=0.505), and ash content (r=0.323).

Table 4. Correlation matrix among storage temperature (°C), storage time (days), phytosanitary product, weight loss (%), dry weight (%), total soluble solids (TSS, °Brix), firmness (N), pH, and ash content (%)

	Storage temperature	Storage time	Phytosanitary product	Weight loss (%)	Dry weight (%)	TSS (°Brix)	Firmness (N)	pH	Ash (%)
Storage temperature	1								
Storage time	0.000	1							
Phytosanitary product	0.000	0.000	1						
Weight loss (%)	0.346(**)	0.849(**)	0.217(**)	1					
Dry weight (%)	0.295(**)	0.505(**)	0.083	0.634(**)	1				
TSS (°Brix)	0.159	0.114	0.089	0.118	0.184(*)	1			
Firmness (N)	-0.289(**)	-0.826(**)	-0.212(*)	-0.874(**)	-0.538(**)	-0.173(*)	1		
pH	0.464(**)	0.766(**)	0.172(*)	0.928(**)	0.605(**)	0.156	-0.847(**)	1	
Ash (%)	0.164	0.323(**)	0.032	0.601(**)	0.382(**)	0.104	-0.551(**)	0.545(**)	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.01 level (2-tailed).

Additionally, a significant linear interdependence was found between storage temperature and the following indicators: weight loss (r=0.346), dry weight content (r=0.295), firmness (r=-0.289), and pH (r=0.464). Notably, significant correlations were also identified between the phytosanitary products applied during the growing season and weight loss (r=0.346), dry weight content (r=0.295), firmness (r=-0.289), and pH (r=0.464). These data suggest that the weight loss, firmness, and pH of fruits during storage may be influenced by the phytosanitary protection practices used during the growing season. Furthermore, significant positive linear relationships were observed between weight loss and dry weight (r=0.634), pH (r=0.928), and ash content (r=0.601). In contrast, the relationship between firmness and weight loss was negative, exhibiting a high intensity (r=-0.874). This is expected, as the turgor of fruits is determined by the water content of the plants; thus, water loss leads to softening of the fruits and a subsequent reduction in commercial quality. Additionally, total soluble solids (TSS) increase as firmness decreases (r=0.173). A significant negative linear relationship was also noted between tomato firmness and ash content (r=-0.551), with the latter increasing due to water loss. Moreover, a decrease in firmness was observed as fruit pH increased, indicating a reduction in organic acid levels within the fruit. This reduction is typical, as organic acids play a crucial role in the post-harvest respiration processes of fruit.

CONCLUSIONS

1. Conventional products (Ortiva Top 0.1%, Cidely Top 0.1%, Amistar 0.1% and Dagonis 0.08%) ensure over 90% efficacy in controlling the pathogens *Alternaria solani*, *Fulvia fulva* and *Botrytis cinerea*, in the tomato crop in greenhouses.
2. Biological products (Cavaler 600SL 3 l/ha, Amulet 4 l/ha, Zytron 1.5 l/ha and Mimoten 3 l/ha) have an efficacy of between 43 and 67% in the control of the pathogens *Alternaria solani, Fulvia fulva* and *Botrytis cinerea*, as a result their use is recommended in case of a low attack or preventive when conditions are favorable for the attack.
3. Phytosanitary treatments applied on the vegetation period significantly influence the firmness and quality of tomatoes during storage. Refrigeration plays a crucial role in preserving these qualities. For organically treated tomatoes, these attributes were superior to those of conventional tomatoes, but only under refrigeration after a storage period of 10 days.
4. Higher temperatures tend to accelerate the deterioration of product quality. Tomatoes treated with conventional phytosanitary products show greater resistance to high temperatures during storage compared to those treated with organic products. Among the conventional treatments, Ortiva Top and Amistar ensured the best results. In the organic category, Cavaler 600SL, Amulet, and Zytron proved to be the most effective.
5. A thorough analysis of the long-term effects of phytosanitary treatments on the nutritional and organoleptic quality of tomatoes is necessary.

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