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Influence of Growing Substrates on the Production Potential and Post-Harvest Storage Capacity of Tomato Fruits from the Buzău 1600 Variety

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Abstract
This study investigated the influence of various growing substrates on the dry matter and total sugar content of *Buzău 1600* tomato fruits, a variety developed at the Buzău Vegetable Research Station and preserved at the Buzău Plant Genetic Resources Bank, Romania. The substrates tested included V1 (Control - Coco peat), V2 (Perlite 2mm), V3 (Perlite 2mm + peat), V4 (Perlite 4mm), V5 (Perlite 4mm + peat), V6 (Perlite 5mm), and V7 (Perlite 5mm + peat). The study further evaluated the effects of a 10-day storage period at 10°C on the fruits grown in V1, V4, V5, V6, and V7 substrates. Results showed that fruits from the V1 (Control - Coco peat) substrate retained more water and had the lowest dry matter content (6.83%), likely due to the higher water retention capacity of peat. In contrast, fruits grown on V4 (Perlite 4mm) and V6 (Perlite 5mm) had a significantly higher dry matter content (7.40% and 7.39%, respectively), indicating better water drainage and aeration in perlite. Mixed substrates (V3 and V5) combining perlite and peat provided an optimal balance between moisture retention and aeration, with V3 (Perlite 2mm + peat) exhibiting the highest dry matter content (7.47%). For total sugar content, fruits from V6 (Perlite 5mm) displayed the highest values at harvest (3.36%), which were well-maintained after storage (3.25%). The sugar-to-acidity ratio was also enhanced in mixed perlite and peat substrates, particularly in V3 (Perlite 2mm + peat), which achieved the highest sugar/acid balance, making the fruits sweeter compared to those grown in the control substrate. Overall, the study concluded that the combination of perlite and peat, particularly in the V3 and V5 treatments, significantly improved fruit quality in terms of dry matter content, sugar content, and sugar-to-acidity ratio, while perlite alone (V6) demonstrated superior sugar retention after storage.

Keywords: Growing Substrates, Tomato Cultivation, Buzău 1600 Variety Dry Matter Content, Total Sugar Content, Post-Harvest Storage

Introduction

Cultivating tomatoes on nutrient substrates such as peat and perlite offers distinct benefits. Peat retains more water, making it ideal for conditions requiring constant moisture, though it has poorer aeration. In contrast, perlite provides excellent drainage and aeration due to its porosity, creating a drier environment that promotes root oxygenation [1, 2]. A mixture of peat and perlite combines the advantages of both, balancing water retention and aeration, which optimizes tomato growth and maintains quality during storage. This combination of substrates is often recommended for greenhouse environments where the precise control of water and air balance is critical for optimal plant development.

In modern agricultural technologies, promoting plant growth and ensuring fruit preservation are key factors for high-quality yields and economic efficiency. According to a study high tunnel cultivation plays a crucial role in the growth and productivity of different tomato varieties, demonstrating the importance of selecting appropriate substrates and growth conditions for optimized results [3]. This allows farmers to tailor growth conditions to maximize both yield and quality, contributing to the economic sustainability of tomato production. Tomatoes are a valuable source of essential phytonutrients, minerals, and nutrients, including lycopene, β-carotene, tocopherol, polyphenols, and ascorbic acid [4, 5]. These compounds not only enhance the nutritional profile of tomatoes but also contribute to their color, taste, and overall market appeal.

A study reported that, while tomatoes can tolerate temperature variations, ensuring a suitable climate is essential for achieving high-quality yields [6], a point supported by [7]. In line with this, a study found that optimizing climatic parameters such as temperature, humidity, and light significantly influences tomato production and fruit quality in greenhouse conditions [8]. Consistent climate control is crucial for maintaining growth cycles and ensuring uniformity in fruit size and quality of different vegetables and crops [9, 10]. Advanced technologies such as automated climate management systems can assist in maintaining these parameters, leading to more reliable production outcomes. Moreover [11, 12], highlighted those innovative solutions allow farmers to manage resources more efficiently, significantly increasing productivity. The use of precision irrigation systems, for instance, which adjust water application based on soil moisture levels, can lead to significant water savings while maintaining optimal growth conditions.

It has been discovered that date palm peat, when used as a substrate, serves as a suitable medium for soilless cultivation due to its favorable physical and chemical properties, as well as its ability to provide essential nutrients [13]. Numerous authors have tested various substrates, including peat, perlite, mineral wool, and coconut fibers under greenhouse conditions, concluding that perlite promotes excellent productivity and earliness [14]. These findings were confirmed by [15, 16, 1], who all observed enhanced yields and earlier fruit development in perlite-grown tomatoes. Moreover, coconut fiber substrates contributed to good fruit quality, particularly in terms of flavor and nutrient density, making them a popular choice in sustainable farming systems. Different further emphasized that inorganic substrates such as mineral wool and perlite produce higher yields and superior quality, which is often difficult to surpass using organic substrates [17, 18].

Material and Methods

The study was conducted at the research greenhouses of USAMV Bucharest using the Buzău 1600 variety, created at the Buzău Vegetable Research Station and currently also conserved at the Buzău Plant Genetic Resources Bank, Romania. The Buzău 1600 variety is characterized by large fruits weighing 200-270 g. The culture was carried out under greenhouse conditions, with the plants being planted in the different types of substrates shown in Table 1.

Table 1: Experimental Variants

Cultivar	Experimental Variant	Substrate Type
Buzău 1600	**V1**	Control - Coco peat
	V2	Perlite 4mm
	V3	Perlite 4mm + peat
	V4	Perlite 5mm
	V5	Perlite 5mm + peat

Fig 1: Climatic chamber and Buzău 1600 variety

At harvest, fruits with an average weight of 240 g were selected. The fruits harvested from the experimental variants regarding the substrate type were weighed, and the content of dry matter and sugars was determined. After storage for 10 days in a climatic chamber, the content of dry matter and sugars was measured. The goal was to observe the changes in dry matter and sugars.

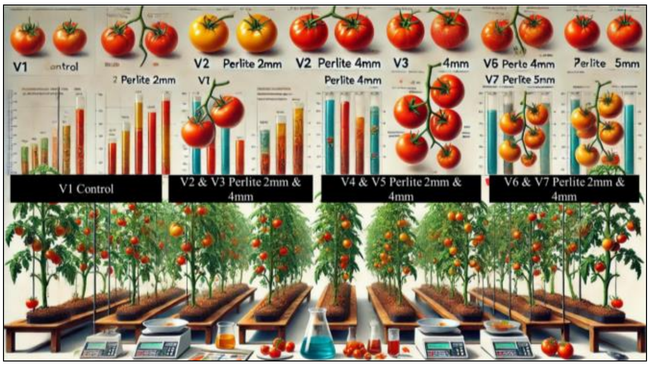

Fig 2: Comparative growth of tomato plants in various substrate

Results and discussions

The normality of the data was assessed using the Shapiro-Wilk test. The results indicated that Dry Substance Content ($W = 0.571$, $p < 0.001$) and Sugars/Total Acidity Ratio ($W = 0.856$, $p = 0.005$) did not follow a normal distribution, while Total Sugar Content ($W = 0.935$, $p = 0.176$) was normally distributed (Table 2). Levene's test for homogeneity of variances revealed that variances were not equal for Dry Substance Content ($F = 3.54$, $p = 0.024$) and Sugars/Total Acidity Ratio ($F = 3.06$, $p = 0.040$), but were equal for Total Sugar Content ($F = 2.20$, $p = 0.105$).

Regarding the interpretation of the results, the one-way ANOVA for Dry Substance Content was marginally significant ($p = 0.051$), suggesting that while there may be differences between treatments, these differences did not meet the conventional threshold for statistical significance. However, post-hoc tests indicated that V1 Control (6.83 ± 1.00) was significantly different from the other treatments. For Total Sugar Content, the ANOVA was highly significant ($p < 0.001$), indicating that the treatments had a strong effect on sugar content. Post-hoc analysis showed that V1 Control (3.21 ± 0.032) was significantly different from most other treatments. The ANOVA for the Sugars/Total Acidity Ratio was also highly significant ($p < 0.001$), demonstrating strong treatment effects, with V1 Control (6.20 ± 0.01) being significantly lower than the other treatments. The highest ratio was observed in V3 Perlit 2mm + peat (8.34 ± 0.02).

Assumption checks revealed violations of normality for Dry Substance Content and Sugars/Total Acidity Ratio, along with heterogeneity of variances for these variables. Therefore, caution should be taken when interpreting the ANOVA results due to these assumption violations.

Table 2: Tomato fruits response to applied Substrate concentrations (Mean ± SD) and Statistical Analysis

Treatment	Dry Substance Content (Mean ± SD)	Total Sugar Content (Mean ± SD)	Sugars/Total Acidity Ratio (Mean ± SD)
V1 Control	6.83 ± 1.00	3.21 ± 0.032	6.20 ± 0.01
V2 Perlite 2mm	7.23 ± 0.06	3.36 ± 0.02	7.79 ± 0.08
V3 Perlite 2mm	7.47 ± 0.06	3.35 ± 0.01	8.34 ± 0.02
V4 Perlite 4mm	7.40 ± 0.10	3.25 ± 0.01	7.80 ± 0.02
V5 Perlite 4mm	7.38 ± 0.03	3.31 ± 0.01	7.56 ± 0.02
V6 Perlite 5mm	7.40 ± 0.02	3.35 ± 0.01	7.93 ± 0.02
V7 Perlite 5mm	7.34 ± 0.05	3.34 ± 0.01	7.41 ± 0.01
p-value	0.051	<0.001	<0.001

p < 0.05 *, 0.01 **, 0.001 ***, ns = non-significant level.

Fig 3 presents data on the dry matter content of various substrates used in plant cultivation, both at harvest and after a 10-day storage period at 10°C. The tested substrates include control peat (V1), different granular sizes of perlite (V2, V4, and V6), and perlite mixed with peat (V3, V5, and V7). The obtained data show variations in the retention of dry matter under these conditions. The initial dry matter content (at harvest) was lowest in V1 (Control - Coco peat), at 6.83%. This lower value could be attributed to the natural properties of peat, which tend to retain more water and have lower structural stability compared to perlite. V2 (Perlite 2mm) shows a slightly higher dry matter content of 7.23%, indicating that smaller granules of perlite contribute to better water drainage and aeration, resulting in higher dry matter. V3 (Perlite 2mm + peat) exhibited the highest dry matter content among all variants at 7.47%, suggesting that the combination of small perlite granules and peat creates an optimal balance between water retention and aeration. V4 (Perlite 4mm) and V5 (Perlite 4mm + peat) show dry matter contents of 7.44% and 7.38%, respectively, with V4 slightly outperforming V5 in terms of dry matter retention, indicating that the addition of peat may slightly reduce the dry matter content compared to pure perlite of the same size. V6 (Perlite 5mm) has a dry matter content of 7.39%, showing that larger granules of perlite behave similarly to smaller ones in terms of water retention at harvest. V7 (Perlite 5mm + peat) shows a slightly lower dry matter content of 7.35%, suggesting that the combination of larger perlite granules with peat does not significantly alter the dry matter content compared to smaller granules.

Analyzing the dry matter content after 10 days of fruit storage at 10°C, a decrease in dry matter content was observed in all variants, as water evaporation continues even during storage, albeit at a slower rate due to the low temperature. In V1 (Control - Coco peat), the dry matter content drops to 6.41%, losing less water compared to the other treatments, and maintaining a higher water content. V2 (Perlite 2mm) shows a similar reduction, dropping to 6.82%, indicating that smaller granules of perlite do not significantly influence moisture retention compared to larger granules. V3 (Perlite 2mm + peat) retained more dry matter at 7.03%, suggesting better moisture retention compared to pure perlite. V4 (Perlite 4mm) and V5 (Perlite 4mm + peat) exhibited dry matter values of 7.01% and 6.88%, respectively, with the peat mixture (V5) providing slightly better moisture retention than perlite alone.For V6 (Perlite 5mm), the dry matter content after storage was 6.82%, similar to the 4mm variant, further confirming that perlite granule size does not significantly affect moisture retention during storage. V7 (Perlite 5mm + peat) had a final dry matter content of 6.81%, indicating that the mixture of peat and perlite at this size retains moisture similarly to the smaller granule mixtures.

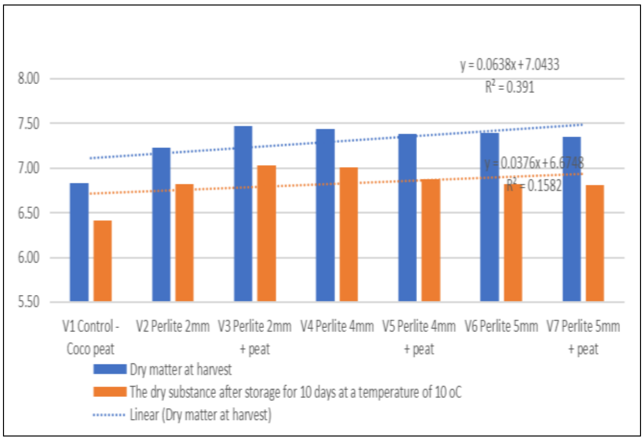

Fig 3: Dry matter content of tomato fruits before and after storage at 10°C

The data in Fig 4 highlight the effect of different substrates on the total sugar content of tomato fruits at harvest and after 10 days of storage at 10°C. The Control (V1 - Coco Peat) shows the lowest sugar values at both stages (3.21 at harvest, 3.08 after storage), indicating that coco peat is less effective in promoting sugar accumulation. V2 (Perlite 2mm) and V3 (Perlite 2mm + Peat) show higher sugar values at harvest (3.36 and 3.35) and after storage (3.23 and 3.21), suggesting that smaller particle sizes of perlite improve sugar retention. V4 (Perlite 4mm) and V5 (Perlite 4mm + Peat) also result in increased sugar content (3.26 and 3.32), though slightly lower than the 2mm perlite variants. The highest sugar levels are recorded for V6 (Perlite 5mm) and V7 (Perlite 5mm + Peat) at harvest (3.36 and 3.34), with V6 maintaining the highest value after storage (3.25). Despite a larger drop in V7 (3.11), the 5mm perlite substrates prove to be the most effective overall.

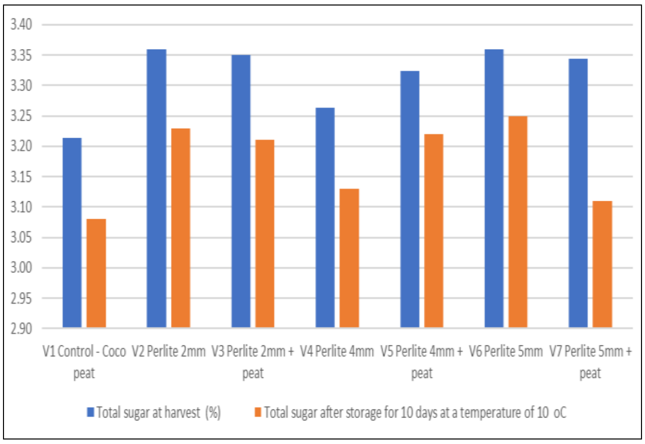

Fig 4: Total Sugar content of Buzău 1600 tomato fruits before and after storage at 10°C

Finally, the Fig 5 shows the **sugar/total acidity ratio**, an important indicator of the sweetness balance. Higher ratios mean less acidity and a sweeter product. The treatments with both perlite and peat, especially V3 (Perlite 2mm + peat), demonstrate the highest sugar/acid ratio, implying a better balance of sweetness compared to the control, which has the lowest ratio. Overall, the data suggests that using perlite and peat combinations not only improves dry substance content and sugar levels but also leads to a more desirable sugar-acid balance, enhancing the quality of the output.

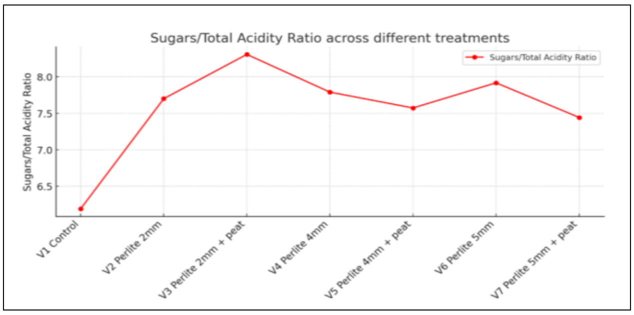

Fig 5: Sugar / Total Acid Ratio content of Buzău 1600 tomato fruits before and after storage at 10°C

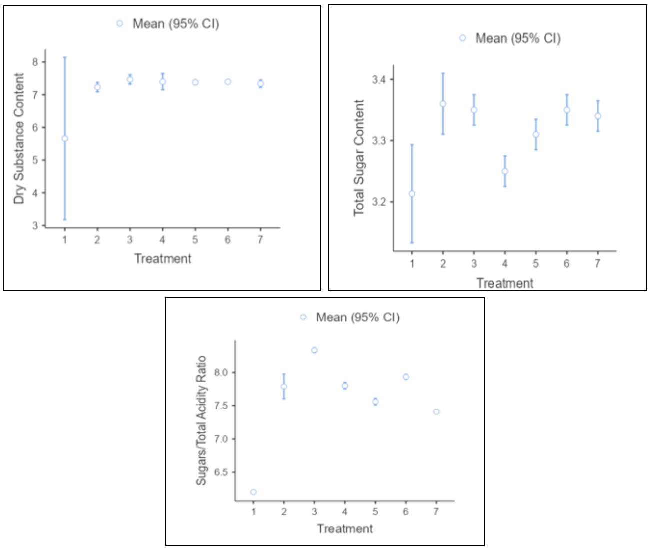

Fig 6: Descriptive Plots.

Discussion

The data from this study provides critical insights into the effects of substrate treatments on tomato fruit quality, focusing on dry substance content, total sugar content, and the sugars/total acidity ratio. The assessment of data normality and variance homogeneity indicated significant deviations from normality and variance equality for dry substance content and sugars/total acidity ratio, suggesting the need for cautious interpretation of the results due to these assumption violations [19]. Despite these limitations, the findings reveal meaningful differences in tomato quality attributes across treatments. The analysis of dry substance content showed marginal significance in the ANOVA ($p = 0.051$), with post-hoc tests identifying significant differences between the control (V1) and other treatments. The V1 (Coco peat) substrate exhibited the lowest dry substance content at harvest (6.83%), consistent with literature indicating that coco peat retains higher moisture due to its inherent water-holding capacity [20]. This characteristic of coco peat can be attributed to its high porosity and fiber content, which contribute to greater water retention compared to other substrates. In contrast, V3 (Perlite 2mm + peat) exhibited the highest dry substance content (7.47%), highlighting the beneficial effects of combining perlite with peat. The perlite component aids in improving aeration and ensuring better drainage, while peat provides moisture retention, creating an optimal balance for plant growth [21]. These findings underscore the importance of substrate structure in influencing water retention and nutrient uptake, aligning with previous research that emphasizes the role of substrate composition in plant growth and productivity [22].

The highly significant ANOVA result for total sugar content ($p < 0.001$) underscores the strong influence of substrate treatments on sugar accumulation in tomatoes. Perlite-based substrates, particularly V6 (Perlite 5mm), resulted in the highest sugar content at harvest (3.36%). This is consistent with prior research linking enhanced aeration and drainage to increased carbohydrate synthesis in fruits [23]. The reduction in sugar content observed after 10 days of storage across all treatments, though expected due to ongoing metabolic processes, was least pronounced in perlite-based substrates. This observation supports reports that perlite enhances post-harvest sugar retention by reducing respiration rates, thus slowing down the degradation of sugars [24]. The sugars/total acidity ratio is a crucial determinant of fruit flavor, and significant treatment effects were observed ($p < 0.001$). The control substrate (V1) exhibited the lowest ratio (6.20), indicative of higher acidity, while V3 (Perlite 2mm + peat) achieved the highest ratio (8.34), suggesting a more favorable sweetness-to-acidity balance. This finding is supported by research that highlights the positive impact of mixed substrates on flavor quality. Specifically, the combination of perlite and organic materials like peat can buffer pH and enhance nutrient availability, leading to an improved sugar-acid balance and, consequently, better flavor quality [25]. The ability of these substrates to buffer pH and improve nutrient availability is crucial for optimizing fruit flavor, as it influences the synthesis of sugar and acid compounds [26, 27].

Conclusions

This study demonstrates that substrate selection significantly affects tomato fruit quality. Perlite, particularly in smaller granules, enhances drainage and dry matter content, making it ideal for drier environments, while peat retains more moisture, beneficial in water-scarce conditions. The optimal results were observed in mixtures of perlite and peat (V_2, V_3 and V_5), which balanced moisture retention and aeration, improving dry matter content, sugar accumulation, and sugar-acid balance at harvest, and maintaining quality during storage. The positive effect on total sugar content and the sugars/total acidity ratio also suggests improved fruit quality. These findings underscore the effectiveness of perlite-peat mixtures in optimizing tomato yield and quality, especially for long-term storage. These combinations not only improved dry matter content at harvest but also enhanced post-harvest quality, making them particularly suitable for extended storage.

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