

Functional Bioactivity and Sensory Attributes of Off-season Mango Influenced by Postharvest Chitosan Coating

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Abstract

The production of off-season mangoes is one of the unique features of some areas in southern India. Apart from the usual mangoes whose harvest period ranges between May and August, there are also specific varieties of mangoes whose off-season harvest period ranges between October and January, thus enabling them to produce throughout the year. Although the market value of the mango is very high, mango fruits are highly perishable during the off-season harvesting, which occurs during monsoon. Thus, the effect of chitosan coating on the sensory and functional qualities of off-season mango variety 'Rumani' fruits stored at ambient temperatures was studied. Different concentrations of chitosan (0%, 0.5%, 1.0% and 1.5%) were used for the off-season mangoes, and some qualities were observed from time to time. Compared to the control group and other treatments, off-season mangoes treated with 1.5% of chitosan had a shelf-life period of 16 days, delayed ripening, low PLW, TSS, respiration rate (RPRT), ethylene evolution rate (EYRT), and α -amylase enzyme activity and high firmness, titratable acidity (TA), and vitamin C content. Also, the fruit that was treated with 1.5% chitosan maintained its good sensory quality characteristics by the end of storage time under ambient conditions, which include total antioxidant capacity (TAC), total phenol content (TPC), and total flavonoid content (TFC). The correlation study revealed that EYRT, RPRT, RR, TSS, PLW and SP are highly positively correlated, while negatively correlated with parameters like FR, TA, ASA, TAC and TPC, influencing the off-season mango fruit quality. Hence, chitosan 1.5% can be incorporated into the supply chain, fetching higher remuneration for producers and retailers as well as receiving greater consumer acceptance.

1. Introduction

The mango (*Mangifera indica* L.), a member of the Anacardiaceae family, is the most significant tropical fruit in terms of its nutrition and economic value. India leads globally, with an annual production of 23.14 million tonnes (44.52% of global mango production) under an area of 2.41 million hectares, with an annual productivity of 9.35 tonnes/ha (Department of Agriculture, Cooperation and Farmers Welfare, 2024). The mangoes exported from India were around 27.33 thousand MT with earnings of 47.98 million USD during the financial year of 2023–2024 (Kumari et al. 2025). The mango fruit gained importance in international markets due to its functional bioactive compounds, which are essential for humans (Bamogo et al. 2025). Even though mango is the most popular fruit for consumers, its availability is restricted for a few months of the year.

Fortunately, off-season cropping of mango is a unique feature of certain tracts of Southern India. Besides the normal crop that matures from May to August, the trees of certain varieties of mango such as 'Neelam', 'Bangalora' and 'Rumani' also mature off-season, bearing two or more crops in succession and extending their bearing period almost till December and sometimes throughout the year (Prasad et al. 2014). The off-season mango cultivation allows the availability of the fruit to consumers throughout the year as well as remuneration to the producers and marketers. But the off-season mango cultivation faces challenges from environmental factors such as pest and disease incidence and untimely rain, which affect the quality and sensory attributes of the fruit. Above all, mango, being a climacteric fruit,

has a shorter shelf life of 2–5 days (Thakur et al. 2022). To nullify the factors leading to quality deterioration after harvest, several postharvest technological interventions such as physical treatments (Hot water, microwave heating, pulsed electric field, cold plasma, etc.) (Terao et al. 2018; Palumbo et al. 2022), chemical treatments (1-MCP, AVG, salicylic acid, hexanol nanoparticle, etc.) (Lather et al. 2026; Idris and Park 2025), edible coatings, etc can be applied. Among the above post-harvest management techniques, edible coatings are gaining importance and are preferred by traders and accepted by consumers due to their environmentally friendly, Generally Recognised as Safe (GRAS) and Sustainable nature.

Chitosan is a biodegradable macromolecule that occurs naturally as an alkaline polysaccharide, which was developed as a result of the deacetylation of bio-functional and nontoxic chitin from crustaceans. Chitosan is one of the well-researched biopolymers, and because of its intrinsic antibacterial activity, low cost, wide availability, nontoxicity, effective film-forming capabilities, and biocompatibility, it has a wide range of potential applications in the food sector (Zhao et al. 2019). Chitosan coating was able to increase and retain the quality of fruits such as banana (Aparna and Giuggioli 2024) and Guava (Krishna and Rao 2017). However, the use of chitosan coatings to prolong shelf life and preserve the quality of mango cv. 'Rumani' has not yet been studied, despite some research into its use as an edible coating on some fruits. Therefore, the effect of chitosan coating on functional bioactive and sensory attributes of off-season mangoes has been experimented and the results were discussed in this article.

2. Materials and Methods

2.1. Selection of fruits

Matured Off-season mangoes cv. 'Rumani' were collected from the nearby mango orchard located in Nagapattinam (10°37'23.5"N 79°51'00.1"E), Tamil Nadu, India during November. The fruits were harvested and allowed to remove field heat in the orchard under a shed. De-sapping was done using egg trays and then packed in plastic crates lined with cushion material to avoid bruising of the fruits during transportation. The fruits were transported to Postharvest Technology Lab (KS214), Department of Horticulture, Central University of Tamil Nadu, Thiruvavur, where the sorting process took place. Fruits were cleaned using potable water and allowed to dry for any excess moisture, and then processed for treatment application.

2.2. Treatments and Sample Preparation

Chitosan solution in different concentrations (0%, 0.5%, 1.0% and 1.5%) was used on off-season mango fruits. In order to prepare 0.5%, 1.0% and 1.5% chitosan solutions, which would be diluted further, acetic acid (1.0%) was mixed with one liter of distilled water. Coating of the fruits was done by immersing the fruits in the chitosan solutions for five minutes and allowing it to dry under a fan. The fruits were then coated, air dried, and packed into CFB boxes. Four replications of each treatment were prepared, consisting of six fruits each, and stored at room temperature (28° - 32°C) and RH (75–80%). At regular intervals, the quality parameters were assessed. Fruits were cut into small pieces with a sterilised knife,

and the pieces were transferred into zip-lock covers according to the treatments and day. The samples were then stored in the deep freezer at -80°C for further analysis.

2.3. Respiration and Ethylene Evolution Rate

The fruits, according to treatments, were confined in an airtight container of known volume for a specified time period at room temperature, and headspace gas concentration of CO_2 and ethylene was estimated by impale the probe of a three-gas analyser (Model: F-950 Felix, USA) into the container through the septa fixed on the sides of the container and direct reading displayed on the instrument screen were noted. The CO_2 evolution was measured in $\text{mg kg}^{-1} \text{h}^{-1}$, while C_2H_4 was measured in $\mu\text{l kg}^{-1} \text{h}^{-1}$ using the formulas below.

2.4. Physiological loss in weight (PLW)

Before storing, the weight of each fruit was measured with an electronic balance (Model: AND, FX-2000, Japan). The weights were also recorded regularly throughout the process of storage. The physiological loss in weight was calculated and expressed as a percentage.

2.5. Firmness

The hardness of the fruit in the equatorial region was assessed by measuring the required force to puncture the fruit with a Lutron Fruit Hardness Tester (Model: FR-5120, Taiwan). The diameter of the probe used was 3 mm. The firmness was calculated and expressed as kg/cm^2 .

2.6. Total Soluble Solids (TSS)

1g of mango pulp was macerated with a pestle and mortar, from which juice was obtained by squeezing the pulp using a muslin cloth. By using a digital refractometer (Model: Atago pocket refractometer range: $0.0\text{--}53.0^{\circ}\text{Brix}$, Japan) and the reading of the juice was obtained, which was expressed in $^{\circ}\text{Brix}$ ($^{\circ}\text{B}$).

2.7. Vitamin C and Titratable Acidity

The Vitamin C content in mango pulp samples was estimated using the DCIP redox visual titration method, while the total titratable acidity of mango pulp samples was assessed using the visual titration method by Ranganna (2005) with some modifications. The unit used to measure was $\text{mg}/100\text{g}$.

2.8. Total Antioxidant, Total Phenols and Total Flavonoids content (mg/mL)

The total antioxidant capacity of was estimated by the Ferric Reducing Antioxidant Power (FRAP) Assay, while the total phenol was estimated by the Folin-Ciocalteu assay and total flavonoids were estimated by using aluminium chloride method as described by Krishna and Rao (2017) with slight modifications. They were measured at 593nm, 700nm and 415nm, respectively, by using a UV (Maker: Thermoscientific, Model: Genesys 180 UV – visible Spectrophotometer, USA).

2.9. Determination of α -amylase activity

The method published by Rama Krishna et al. (2020) was used to measure the activity of α-amylase in mango fruit pulp, using the di-nitro salicylic acid (DNS) method with minor modification. 1.0 g were used to estimate the activity of α-amylase. The homogenization process for the mango pulp was carried out using 0.5 M NaCl solution and 10mL of 16 mM sodium acetate buffer (pH 4.8). The mixture was centrifuged at 4 °C for 10 minutes at 10,000 rpm. 500 liters of supernatant was mixed with a reaction mixture which consisted of 0.5mL of 1% (w/v) starch dissolved in the same extraction buffer. Incubation of the mixture was done for 30 minutes at 20° C. In addition, the above mentioned ingredients were kept in a zero time blank. The reaction was stopped by boiling the mixture in hot water for five minutes and 0.5 ml of Dinitro Salicylic Acid (DNS) reagent was added to the mixture. The volume of the mixture at this point was 20 milliliters and its absorbance was determined at 540nm using a spectrophotometer (Spectrophotometer Model: Genesys 180 UV–visible Spectrophotometer; Made in the USA; Company: Thermo Scientific).

2.10. Ripening rate of coefficient

A rating from 1 to 5 was given for each level of ripeness (1 – unripe, 2 – quarter ripe, 3 – semi-ripe, 4 – ¾ ripe, and 5 – fully ripe). Below are the formulae for calculating the ripening coefficient:

Coefficient of ripening = $\frac{\sum (\text{No. of fruits at a particular ripening stage} \times \text{its score})}{\text{Total number of fruits}}$
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2.11. Spoilage %

The fruits were tallied and calculated starting on the day that the first visual signs of rot were observed on the fruits and calculated based on the formula mentioned below and they were expressed as %.

Spoilage % = $\frac{\text{No. of spoiled fruits}}{\text{Total No. of fruits}} \times 100$

2.12. Organoleptic quality

To find out whether customers would find the coated fruits satisfactory, an organoleptic quality test was done. On the 16th day of storage, untrained panellists (30 no.) rated the samples for green colour, aroma, firmness, appearance, and overall Acceptability on a 9-point Hedonic-sensory rating, where 1 sensory score was for ‘dislike extremely’, and 9 was for ‘like extremely’.

2.13. Statistical analysis

SPSS Statistics 20.0 software package was employed for the analysis of the statistical data (SPSS Inc. US). For the determination of the significance of mean differences, Duncan’s multiple range test was applied at the level of $p \leq 0.05$. For the determination of the significance of the differences between treatments, one-way ANOVA was used. The Pearson correlation was carried out using Origin 2026 software (Origin Lab, USA).

3. Results and discussion

3.1 Respiration and Ethylene Evolution Rate

The fruit post-harvest physiology is determined by its respiration rate, which regulates cellular functions in response to nutrient depletion and fruit senescence (Liu et al. 2025). The results revealed that (Fig. 1A), during the storage period, the climacteric peak was observed in fruit treated with chitosan 0.5% and control between the 13th and 14th day of storage. However, chitosan 1% treated fruit showed a respiratory climacteric peak on 15th day, while no such climacteric peak was observed in fruits treated with chitosan 1.5%. By the end of the storage period, the fruits treated with chitosan 1.5% ($222.39 \text{ mg kg}^{-1} \text{ h}^{-1}$) and chitosan 1% ($239.66 \text{ mg kg}^{-1} \text{ h}^{-1}$) showed significantly lower values when compared to control ($267.07 \text{ mg kg}^{-1} \text{ h}^{-1}$). Fruit coated with chitosan 0.5% was spoiled on the 14th day.

Similarly, the ethylene rate started to rise from the 9th day onwards and reached its peak between the 13th and 14th days of storage, with higher ethylene evolution rates observed in the control ($601.27 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$) and chitosan 0.5% ($574.46 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$) (Fig. 1B). While the fruit treated with chitosan 1.5% has the least ($345.36 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$) ethylene evolution rate. At the end of storage period (16th day of storage), chitosan 1.5% ($251.77 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$) had the lowest ethylene evolution rate, followed by chitosan 1.0% ($315.58 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$), then control ($369.44 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$) (Fig. 1B).

Based on the results, the fruits treated with 1.5% chitosan showed lower respiration and ethylene production rates than all other treatments. The chitosan coating acts as a semipermeable membrane over the fruit, which regulates the gaseous exchange between the fruit and the atmosphere (Dutta et al. 2016). This would have led to a modified atmosphere, increasing the CO_2 concentration in the internal tissue space of the fruit mesocarp. The increased CO_2 concentration would have slowed down the respiration rate and acted as an antagonist, suppressing ethylene production (Wills and Golding 2016). The fruit coated with chitosan 0.5% spoiled during the 14th day of storage; this might be due to the acetic acid used to solubilise chitosan in water, which might have induced the hydrolysis of protopectin, which is present in the cell wall, due to which pectin degradation might have taken place and spoilage of fruit happened (Jong et al. 2023). Similar results were obtained in fruits treated with chitosan, such as in guava and Cavendish banana (Krishna and Rao 2017; Hosseini et al. 2018).

3.2 Physiological loss in weight (PLW%)

Physiological weight loss in fruits is due to the water loss that happens in the fruits due to respiration and moisture gradient difference between the fruit surface and atmosphere. In Fig. 1C, it was observed that the physiological loss in weight showed an increasing trend irrespective of treatments throughout the storage period. However, it was observed that the fruits treated with chitosan 1.5% showed a lower physiological loss in weight (14.45%) compared to all treatments, i.e., chitosan 1.0% (16.17%) and control (16.43%) at the 16th day of storage. Fruit coated with chitosan 0.5% was spoiled on 14th day with PLW of 13.66%. This might be due to the semi-permeable nature of the chitosan film on the surface

of the mango fruit, which would have selectively limited the moisture exchange between the fruit and the atmosphere (Barman et al. 2017). Similar results were observed in chitosan-treated fruits, such as the strawberry and apricot (Alniak et al. 2025; Al-Temimi et al. 2026).

3.3 Firmness

Firmness is referred to as a textural characteristic that denotes the maturity or quality of the fruit (Musacchi and Serra 2018). In this experiment (Fig. 1D), it was observed that fruit firmness decreased throughout the storage period, regardless of treatment. But at the end of the storage period, the fruits coated with chitosan 1.5% showed a higher firmness of 3.75 kg/cm², followed by chitosan 1.0% (2.95 kg/cm²) when compared to control (1.66 Kg/cm²). This reduction in firmness may be due to the breakdown of pectin during metabolism. But the fruits treated with chitosan 1.5% showed higher firmness. This might be due to chitosan coating acting as a barrier that prevented moisture loss, preserving the fruit turgidity. Due to this layer, the fruit's metabolic activity might have slowed, thereby slowing down the cell wall enzyme hydrolytic activity (Yi et al. 2025), leading to slower conversion of proto-pectin to soluble pectin. A similar retention in fruit firmness due to chitosan coating was observed in Indian jujube (Hesami et al. 2021).

Note

* Chitosan 0.5% treated fruits have spoiled on 14th day, thereby no readings were taken further.

3.4 Total soluble solids

TSS represents the soluble solids, which indicate the level of sweetness in the fruit pulp (Kusumiyati et al. 2020). At first, the fruits of all treatments showed a decreasing trend in TSS until the 4th day. Thereafter, there was an increase in TSS from a mean of 7.5 °Brix to a range of 9.3 to 11.7 °Brix. At the end of the storage period, the fruits treated with chitosan 1.5% showed a lower TSS (9.75 °Brix) when compared to all other treatments, as shown in Fig. 2A. From the day of harvest until the 4th day of storage, a decrease in TSS was observed might be due to the pre-climacteric phase of the fruit (Alonso - Salinas et al. 2024), in which due to the detachment of fruit from the source, the mature fruits utilise the sugars as temporary respiratory substrates before the actual activation of sugar hydrolysing enzymes (Yao et al. 2014). But after the 4th day of storage, the fruits entered the ripening phase, where the hydrolysis of sugar takes place and the TSS value of the fruit increased with respect to all treatments. When compared to the control, the fruits treated with chitosan coating 1.5% showed a lower TSS value due to the lowered metabolic activities of the fruit, which was bestowed by the semi-permeable nature of chitosan (Parvin et al. 2023) that has slowed down the respiratory catabolic process. A similar type of results were observed in ber fruits by Hesami et al. (2021) and guava by Krishna and Rao (2017).

3.5 α-amylase activity

The conversion of starch to simple sugars is a measure of fruit ripening and it can be analysed by measuring the α-amylase enzyme activity. In this experiment, it was observed that throughout the

storage period, regardless of treatment, fruits showed an increasing trend during ripening and a decreasing trend during the post-ripening phase as shown in Fig. 2B. The conversion of starch to sugar in control fruit by α -amylase enzyme (4.57–33.70 μM) was found to be high when compared to chitosan 1.5% coated (8.6–30.10 μM) fruit during the storage period. While chitosan 1% coated fruits recorded α -amylase enzyme activity in the range of 7.97–34.12 μM , while chitosan 0.5% recorded the highest α -amylase enzyme activity (38.40 μM) on 12th day of storage. The α -amylase enzyme activity results correlate with the TSS data presented (Fig. 2A). This enzyme breaks the bond between carbohydrates, which leads to the hydrolysis of starch to sugars in fruit (Ma et al. 2015). The α -amylase activity in developing mango fruits increased, leading to a parallel increase in TSS values. A similar kind of results were observed in ‘Sukkari’ bananas by Awad et al. 2017, where it was noted that the chitosan coating had a positive effect in retarding α -amylase enzyme activity.

3.6 Titrable Acidity

The results as seen in Fig. 2C revealed that the titrable acidity of fruit coated with different concentrations of chitosan, along with the control, showed a decreasing trend throughout the storage period. However, at the end of the storage period, it was observed that the fruit with chitosan 1.5% (0.047%) retained higher titrable acidity than other treatments, such as chitosan 1.0% (0.044%), control (0.043%). Citric and malic acids are the two main organic acids present in mango (Lebaka et al. 2021). In general, due to the consumption of organic acid as a respiratory substrate, the titrable acidity decreases in fruit after harvest (Maldonado-Celis et al. 2019). As the fruit treated with chitosan were provided with a semi-permeable membrane, which reduces the respiration rate, thereby slowing down degradation of organic acids (Vilvert et al. 2022). Similarly, slow degradation of organic acid was observed in ‘Taimang’ mango, and ‘Cavendish’ banana (Wu et al. 2026; Roidoung et al. 2025).

3.7 Vitamin C Content

In fruits, vitamin C regulates fruit ripening and the cellular redox state by eliminating ROS (Arabia et al. 2024). However, the stability of vitamin C is highly susceptible to degradation during the metabolic processes of fruits (Verma et al. 2026). The experimental results revealed that the vitamin C content of the fruit reduced during the storage period irrespective of the treatments (Fig. 2D). However, at the end of storage period, the fruit treated with Chitosan 1.5% (20.42 mg/100g) and Chitosan 1.0% (17.41 mg/100g) had significantly higher values of vitamin C than and Control (15.06 mg/100g). Vitamin C plays a crucial role in averting free radicals, acting as an antioxidant as well as a substrate in the catabolic and anabolic activities of the fruit (Verma et al. 2026). This addresses the reduction in vitamin C content during the storage period. The chitosan coating would have slowed down the respiration and catabolic processes, retaining higher vitamin C in the chitosan fruit (Sun et al. 2018). Similar results were observed by Hesami et al. (2021) and Saleem et al. (2021) in ber and strawberry, respectively.

Figure 2

Influence of chitosan coating on the TSS (A), α -amylase Activity (B), Titrable acidity (C) and Vitamin-C content (D) of the off-season mango cv. ‘Rumani’.

3.8 Total phenols and Flavonoid content

Phenolic compounds present in fruits act as antioxidants, substrates for oxidation reactions, and enhancers of organoleptic and nutritional qualities (Ahmad et al. 2025). Flavonoids generally belong to polyphenols, which contribute to plant protection, pigment and flavour development in fruit (Chen et al. 2022). At the end of storage period, the fruits treated with chitosan 1.5% (27.76 and 9.54 mg/ml) showed higher phenol and flavonoid content when compared to control (11.46 and 5.16 mg/ml) and chitosan 1% (18.80 and 5.70 mg/ml) treatments, respectively (Fig. 3A and B). The lowering of phenol and flavonoid content might be due to polyphenol oxidase activity and formation of ROS during ripening and senescence, the cellular structural break, which would have led to lower phenolic and flavonoid content (Kassem et al. 2022; Lattanzio et al. 2009). In this study, initially the mango fruits showed lower phenol content and again showed a rise in phenol content and maintained, which might be due to the abiotic stress induced by the chitosan coating (Ngubane et al. 2024) i.e., the semipermeable layer formed by chitosan coating might have averted the PPO activity and activated the antioxidant enzyme, thereby protecting the stability of the cell, increasing the shelf life of the mango fruit with higher phenol content. Similar results were observed with respect to the study conducted by Wang and Gao. (2013) in strawberry and Krishna and Rao. (2017) in guava.

3.9 Total Antioxidants

Antioxidants help reduce ROS (Reactive Oxygen Species) in the fruit after harvest, which are the by-products of metabolism (Lobo et al. 2010). Antioxidant capacity was retained highest in the fruits treated with Chitosan coating 1.5% (179.26 mg/ml), followed by 1.0% (175.34%). Whereas the control (100.53 mg/ml) showed a drastic reduction in the levels of antioxidant capacity of the fruit, as shown in Fig. 3C. When fruits are stored at room temperature for an extended period, the fruit showed a decreased trend of antioxidant capacity (Kumar et al. 2021). In this study, it was also observed that the antioxidant capacity was reduced in all treatments. But, the lows and highs at the beginning of the storage period might be due to the utilization of the antioxidants and the action of different antioxidant enzymes at different stages of fruit to counteract the rise of free radicals (ROS) formed due to postharvest ripening (Vall Llaure et al. 2022). The rise of antioxidants might be due to the synthesis of antioxidant enzymes to tackle the oxidative damage caused by ROS during the ripening and senescence process over the storage period (Wei et al. 2025). The chitosan-coated mango fruits retained higher antioxidant capacity than the control at the end of the storage period, which might be due to its semipermeable layer, hindering the respiration catabolism of the fruit (Chitravathi et al. 2015). A similar result were observed by Saleem et al. (2021) in strawberry and Popesco et al. (2022) in apple.

3.10 Ripening Rate of Co-efficient

As shown in Fig. 4B, despite the treatment used, there was an increase in the ripening rate of the mango fruits stored at room temperature, from the date of harvest up to the end of their storage period. Nevertheless, the ripening rate of the fruits treated with 1.5% chitosan (3.92) was more delayed than that of the other treatments, including the control (4.85). The 1.5% chitosan-treated mango fruit reached $\frac{3}{4}$ th

ripening stage, whereas control and other treated fruit reached full ripened stage. This reduced rate of ripening might be due to a reduction in metabolic activity of fruit, such as chlorophyll degradation (Wantat et al. 2021). As well as reduced ethylene production by modification of the internal atmosphere of the fruit created by chitosan coating, resulting in slower ripening. Similar results of reduced ripening rate by chitosan coating were confirmed in papaya (Singh et al. 2024).

3.11 Spoilage %

The percentage of fruits showing spoilage increased during the storage period irrespective of treatments. The first appearance of spoilage was recorded on 8th day of storage in chitosan 0.5% (23%), while control and other treatments recorded no spoilage. At the end of storage period, control recorded 30% fruit spoilage, while chitosan 1.5% (15%) recorded least spoilage of fruits, followed by chitosan 1% (20%). Chitosan 0.5% treated fruits had 100% spoilage by 14th day, as shown in Fig. 5 (A). Lower spoilage in chitosan-treated fruits might be due to its antimicrobial property, i.e., the ability to change the cell permeability interaction between polycationic chitosan and electronegative charges of microbial cell surface. These interactions might have led to the leakage of intracellular electrolytes and proteinous constituents of the microbial cell (Singh et al. 2024). The present results are in agreement with Algarni et al. (2022), who reported that the spoilage percentage was retarded in apricot fruit coated with chitosan. Whereas 100% fruit spoilage in chitosan 0.5% might be due to the higher concentration of acetic acid (1%) which was used to dissolve 0.5% chitosan. The high concentration of acetic acid might have hydrolysed the cell wall of the fruit pericarp, weakening the first defence, thereby recording higher fruit spoilage. Similar negative results of acetic acid treated guava fruits were reported by Krishna and Rao (2014).

3.12 Sensory Evaluation

A sensory evaluation was conducted by the panellists to evaluate parameters such as retention of green colour, aroma, firmness, appearance, and overall acceptance. On the basis of the score given by the panellists (Fig. 5B), the fruits of chitosan 1.5% (7) have a higher overall acceptance (scored higher for green colour, aroma, firmness, and appearance) value when compared to other treatments such as chitosan 1% (4), control (4) and least score was given to chitosan 0.5% (3). The ability of chitosan 1.5% in the formation of semi permeable layer around the fruit would have created a modified atmosphere enriched with carbon dioxide in the intercellular spaces due to which the respiration rate, ethylene evolution rate and catabolic process have been slow down leading to higher retention of green color (Chlorophyll) (Wantat et al. 2021), firmness (Hesami et al. 2021) and flavonoids (aroma) (Wang and Gao 2013). This resulted in a better appearance of fruit and overall acceptability by the consumer.

3.13 Correlation Analysis

As shown in Fig. 6, TSS is highly positively correlated with RPRT (0.88), PLW (0.80), and RR (0.74), while it is moderately positively correlated with SP (0.58) and EYRT (0.62). TSS is highly negatively correlated with FR (-0.82), moderately negatively correlated with TPC (-0.58), TA (-0.57) & TF (-0.50), which implies

that TSS increases with higher respiration and ripening rates; consequently, PLW and spoilage also increase. Ascorbic acid content is moderately positively correlated to titrable acidity (0.68) and Total antioxidant capacity (0.63). This signifies that due to the retention of higher vitamin C content, it would also contribute to fruits with higher titrable acidity as well as higher antioxidant capacity. Further, the antioxidant capacity of the fruits is more positively correlated with the total phenolic content (0.66) than that of total flavonoid content (0.34). For spoilage of the fruits, ethylene evolution rate has shown a highly positive correlation (0.88) and contributes significantly, leading to higher ripening rate (0.91) and moisture loss (0.67). While spoilage is highly negatively correlated with firmness (-0.84), which indicates the loss of firmness of the fruit would lead to higher spoilage. It can also be inferred that an increase in the ripening coefficient rate (- 0.90) would lead to a negative impact on firmness.

4. Conclusion

Off-season mango production is unique to some areas in southern India. Apart from the regular production of mango that matures between May and August, some varieties of mango produce an off-season production that matures between October and January and thus makes the variety bear fruit throughout the year. But the rainy season falls in the off-season bearing and therefore makes the mango fruit highly susceptible to deterioration. Nevertheless, even though the off-season mango fetches a high price in the market, the income generated from it is extremely small, and the fruits are covered in chitosan. The chitosan, being a naturally derived GRAS chemical compound, can be a better alternative in a growing synthetic chemical coating environment. Chitosan has proved to extend the shelf life of the off - season mango fruit, retaining nutrition and consumer acceptance. Thereby, chitosan 1.5% showed good physical, physiological, biochemical, as well as maintained nutritional and sensory quality attributes of off-season mango fruit. The chitosan treatment has extended the shelf life of the off-season mango fruits to 16 days at room-temperature storage. The application of chitosan coating onto the off - season fruits like mango will certainly fetch higher profits to the producers but also keep the fruit processing industry functional in the lean period, as the availability of the mango fruits is assured.

Declarations

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Credit authorship contribution statement

Iniya Bharathi. R (I. B. R.): investigation, original draft preparation, data collection, data curation, graph preparation and data analysis; Rama Krishna. K (R. K. K): conceptualization, methodology development, supervision of work, draft reviewing, editing. The authors have read and approved the manuscript.

Data availability

The data supporting this study are provided within the paper.

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Generative AI Declaration

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References

1. Ahmad Z, Rauf A, Orhan IE, Mubarak MS, Akram Z, Islam MR, Imran M, Edis Z, Kondapavuluri BK, Thangavelu L, Thiruvengadam M. Antioxidant potential of polyphenolic compounds, sources, extraction, purification and characterization techniques: a focused review. *Food Sci Nutr*. 2025;13(12):e71259.
2. Algarni EH, Elnaggar IA, Abd El-wahed AEWN, Taha IM, Al-Jumayi HA, Elhamamsy SM, Mahmoud SF, Fahmy A. Effect of chitosan nanoparticles as edible coating on the storability and quality of apricot fruits. *Polymers (Basel)*. 2022;14(11):2227.
3. Alniak NY, Caner C, Yüceer M. The individual and combined effects of electrolyzed water and chitosan coating applications on the storage stability of fresh strawberries. *Food Bioprocess Technol*. 2025;18(6):5683–99.
4. Alonso-Salinas R, López-Miranda S, Pérez-López AJ, Acosta-Motos JR. Strategies to delay ethylene-mediated ripening in climacteric fruits: implications for shelf life extension and postharvest quality. *Horticulturae*. 2024;10(8):840.
5. Al-Temimi AA, Al-Hilifi SA, Al-Ali RM, Dinh LN, Yao Y, Agarwal V. Hyaluronic acid/chitosan/pectin based edible composite antioxidant coatings for the preservation of fresh apricots. *Sustain Food Technol*. 2026. [Epub ahead of print].
6. Anonymous. Horticulture statistics at a glance. New Delhi: Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India; 2024.

7. Aparna M, Giuggioli NR. Chitosan based edible coatings: enhancing shelf life and quality in fruits and vegetables. *J Adv Biol Biotechnol*. 2024;27(11):178–91.
8. Arabia A, Munné-Bosch S, Munoz P. Ascorbic acid as a master redox regulator of fruit ripening. *Postharvest Biol Technol*. 2024; 207:112614.
9. Awad M, Al-Qurashi A, Mohamed S, El-Shishtawy R, Ali M. Postharvest chitosan, gallic acid and chitosan gallate treatments effects on shelf life quality, antioxidant compounds, free radical scavenging capacity and enzymes activities of 'Sukkari' bananas. *J Food Sci Technol*. 2017;54(2).
10. Bamogo WM, Tankoano A, Guissou WA, Traoré MAE, Kante-Traore H, Parkouda C, Savadogo A. Nutritional composition and bioactive compound of mango kernels and peels: valorization of by-products. *Food Humanit*. 2025:100971.
11. Barman K, Patel VB, Sharma S, Singh RR. Effect of chitosan coating on postharvest diseases and fruit quality of mango (*Mangifera indica*). 2017.
12. Chen JH, Hou N, Xv X, Zhang D, Fan TQ, Zhang QX, Huang YJ. Flavonoid synthesis and metabolism during the fruit development in hickory (*Carya cathayensis*). *Front Plant Sci*. 2022; 13:896421.
13. Chitravathi K, Chauhan OP, Raju PS. Influence of modified atmosphere packaging on shelf-life of green chillies (*Capsicum annuum* L.). *Food Packag Shelf Life*. 2015; 4:1–9.
14. Dutta P, Dey K, Ghosh A, Bhowmick N, Ghosh A. Effect of edible coatings for enhancing shelf-life and quality in Ber (*Zizyphus mauritiana* Lamk.) fruits. *J Appl Nat Sci*. 2016;8(3):1421.
15. Hesami A, Kavooosi S, Khademi R, Sarikhani S. Effect of chitosan coating and storage temperature on shelf-life and fruit quality of *Zizyphus mauritiana*. *Int J Fruit Sci*. 2021;21(1):509–18.
16. Hosseini MS, Zahedi SM, Abadía J, Karimi M. Effects of postharvest treatments with chitosan and putrescine to maintain quality and extend shelf-life of two banana cultivars. *Food Sci Nutr*. 2018;6(5):1328–37.
17. Idris YD, Park T. Hexanal nanotechnology: a sustainable strategy for extending the shelf-life and preserving the quality of fruits and vegetables. *Precis Agric Sci Technol*. 2025;7(3):228–42.
18. Jong SH, Abdullah N, Muhammad N. Effect of acid type and concentration on the yield, purity, and esterification degree of pectin extracted from durian rinds. *Results Eng*. 2023; 17:100974.
19. Kassem HS, Tarabih ME, Ismail H, Eleryan EE. Influence of nano-silica/chitosan film coating on the quality of 'Tommy Atkins' mango. *Processes*. 2022; 10:279.
20. Krishna KR, Rao DS. Effect of chitosan coating on the physiochemical characteristics of guava (*Psidium guajava* L.) fruits during storage at room temperature. *Indian J Sci Technol*. 2014;7(5):554.
21. Krishna KR, Rao SDV. Influence of chitosan coating and storage temperatures on postharvest quality of guava. *Indian J Hortic*. 2017; 74:466–70.
22. Kumar N, Petkoska AT, Al-Hilifi SA, Fawole OA. Effect of chitosan-pullulan composite edible coating functionalized with pomegranate peel extract on the shelf life of mango (*Mangifera indica*). *Coatings*. 2021;11(7):764.

23. Kumari I, Singh AK, Dimri DC, Singh KP, Nand V, Shivran JS, Gaurav K, Divya, Gangola S, Mitra D, Chattaraj S. Pre-harvest bagging modulates fruit traits, phytochemical profiles and disease incidence in mango (*Mangifera indica* L.) cv. Mallika. *Sci Rep.* 2025;15(1):42533.
24. Kusumiyati, Hadiwijaya Y, Putri IE, Mubarak S, Hamdani JS. Rapid and non-destructive prediction of total soluble solids of guava fruits at various storage periods using handheld near-infrared instrument. *IOP Conf Ser Earth Environ Sci.* 2020;458(1):012022.
25. Lather R, Rani A, Kumar S, Mehta A, Pradhan V, Acharya A. Postharvest chemical treatments for extending shelf life and preserving fruit quality. *J Adv Biol Biotechnol.* 2026;29(3):273–87.
26. Lattanzio V, Kroon PA, Quideau S, Treutter D. Plant phenolics-secondary metabolites with diverse functions. *Recent Adv Polyphenol Res.* 2009; 1:1–35.
27. Lebaka VR, Wee YJ, Ye W, Korivi M. Nutritional composition and bioactive compounds in three different parts of mango fruit. *Int J Environ Res Public Health.* 2021;18(2):741.
28. Liu C, Liu K, Wang W, Wu W, Dong H, Wu Y, Pan J, Liao W, Yang X, He Q. Exploring the impact of respiration on pectin metabolism through a quantitative respiratory system created by equilibrium modified atmosphere packaging with adjustable gas-conductor materials. *Int J Biol Macromol.* 2025; 307:142331.
29. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: impact on human health. *Pharmacogn Rev.* 2010;4(8):118.
30. Ma YY, Zhao DG, Zhou AY, Zhang Y, Du Z, Zhang K. α -Glucosidase inhibition and antihyperglycemic activity of phenolics from the flowers of *Edgeworthia gardneri*. *J Agric Food Chem.* 2015;63(37):8162–9.
31. Maldonado-Celis ME, Yahia EM, Bedoya R, Landázuri P, Loango N, Aguillón J, Restrepo B, Guerrero Ospina JC. Chemical composition of mango (*Mangifera indica* L.) fruit: nutritional and phytochemical compounds. *Front Plant Sci.* 2019; 10:1073.
32. Musacchi S, Serra S. Apple fruit quality: overview on pre-harvest factors. *Sci Hortic.* 2018; 234:409–30.
33. Ngubane S, Tesfay SZ, Magwaza LS, Mditshwa A. The effect of composite edible coatings on the postharvest quality of "Hass" avocado fruit treated at different harvest maturities. *Front Sustain Food Syst.* 2024; 8:1473731.
34. Palumbo M, Attolico G, Capozzi V, Cozzolino R, Corvino A, De Chiara MLV, Pace B, Pelosi S, Ricci I, Romaniello R, Cefola M. Emerging postharvest technologies to enhance the shelf-life of fruit and vegetables: an overview. *Foods.* 2022;11(23):3925.
35. Parvin N, Rahman A, Roy J, Rashid MH, Paul NC, Mahamud MA, Imran S, Sakil MA, Uddin FJ, Molla ME, Khan MA. Chitosan coating improves postharvest shelf-life of mango (*Mangifera indica* L.). *Horticulturae.* 2023;9(1):64.
36. Popescu PA, Palade LM, Nicolae IC, Popa EE, Miteluț AC, Drăghici MC, Matei F, Popa ME. Chitosan-based edible coatings containing essential oils to preserve the shelf life and postharvest quality parameters of organic strawberries and apples during cold storage. *Foods.* 2022;11(21):3317.

37. Prasad SS, Reddy YTN, Upreti KK, Rajeshwara AN. Studies on changes in carbohydrate metabolism in regular bearing and "off" season bearing cultivars of mango (*Mangifera indica* L.) during flowering. *Int J Fruit Sci.* 2014;14(4):437–59.
38. Rama Krishna K, Sharma RR, Srivastav M. Physiological and biochemical attributes associated with jelly-seed disorder in mango (*Mangifera indica* L.). *Acta Physiol Plant.* 2020; 42(6):90.
39. Ranganna S. Handbook of analysis and quality control for fruits and vegetable products. 3rd ed. New Delhi: Tata McGraw-Hill; 2005.
40. Roidoung S, Wongsudtho S, Pongsanhan M, Samsudin H, Sogi DS. Effect of nanoclay in chitosan-based coating on ripening retardation of banana fruits. *Discov Food.* 2025;5(1):152.
41. Saleem MS, Anjum MA, Naz S, Ali S, Hussain S, Azam M, Sardar H, Khaliq G, Canan İ, Ejaz S. Incorporation of ascorbic acid in chitosan-based edible coating improves postharvest quality and storability of strawberry fruits. *Int J Biol Macromol.* 2021; 189:160–9.
42. Singh H, Bhasin JK, Dash KK, Shams R, Béla K. Effect of chitosan based edible coating in management of post harvest losses in papaya: a comprehensive review. *Appl Food Res.* 2024;4(2):100456.
43. Sun Y, Li M, Mitra S, Hafiz Muhammad R, Debnath B, Lu X, Jian H, Qiu D. Comparative phytochemical profiles and antioxidant enzyme activity analyses of the southern highbush blueberry (*Vaccinium corymbosum*) at different developmental stages. *Molecules.* 2018;23(9):2209.
44. Terao D, Nechet KDL, Frighetto RTS, Anjos VDDA, Benato EA, Halfeld-Vieira BDA. Physical postharvest treatments in the control of stem-end rot of mango. *J Phytopathol.* 2018;166(7–8):581–9.
45. Thakur RR, Mangaraj S, Kate AE, Sami R, Al-Mushhin AA, Maklad MF, Uguru H, Helal M. Effect of harvesting stages and storage temperature on quality attributes and post-harvest shelf-life of mango (*Mangifera indica*). *J Biobased Mater Bioenergy.* 2022;16(5):770–82.
46. Vall-Llaura N, Fernández-Cancelo P, Nativitas-Lima I, Echeverria G, Teixidó N, Larrigaudière C, Torres R, Giné-Bordonaba J. ROS-scavenging-associated transcriptional and biochemical shifts during nectarine fruit development and ripening. *Plant Physiol Biochem.* 2022; 171:38–48.
47. Verma K, Nema PK, Badgujar PC, Venkatesh K, Rajendran A, Loushigam GL. Vitamin C in fruits and vegetables: stability, processing effects, analytical detection, nutrient interactions, bioavailability, and health implications. *Food Chem.* 2026:148058.
48. Vilvert JC, de Freitas ST, Ferreira MAR, de Lima Leite RH, dos Santos FKG, Costa CDSR, Aroucha EMM. Chitosan and graphene oxide-based biodegradable bags: an eco-friendly and effective packaging alternative to maintain postharvest quality of 'Palmer' mango. *LWT.* 2022; 154:112741.
49. Wang SY, Gao H. Effect of chitosan-based edible coating on antioxidants, antioxidant enzyme system, and postharvest fruit quality of strawberries (*Fragaria x ananassa* Duch.). *LWT Food Sci Technol.* 2013;52(2):71–9.
50. Wantat A, Rojsitthisak P, Seraypheap K. Inhibitory effects of high molecular weight chitosan coating on 'Hom Thong' banana fruit softening. *Food Packag Shelf Life.* 2021; 29:100731.

51. Wei W, Liu Z, Pan X, Yang T, An C, Wang Y, Li L, Liao W, Wang C. Effects of reactive oxygen species on fruit ripening and postharvest fruit quality. *Plant Sci.* 2025; 352:112391.
52. Wills RBH, Golding JB. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*. 6th ed. Wallingford: CABI; 2016.
53. Wu Z, Zhang B, Qiao Q, Lin Z, Ren Z. Synergistic effects of a chitosan-pectate composite coating on postharvest preservation and underlying mechanisms in mango fruit. *LWT.* 2026:119000.
54. Yao BN, Tano K, Konan HK, Bédié GK, Oulé MK, Koffi-Nevry R, Arul J. The role of hydrolases in the loss of firmness and of the changes in sugar content during the post-harvest maturation of *Carica papaya* L. var solo 8. *J Food Sci Technol.* 2014;51(11):3309–16.
55. Yi G, Fan S, Wu H, Khan A, Priyadarshi R, Sun W, Lin D, Zhang Y. Chitosan-based coatings and films: mechanisms and applications in postharvest preservation of mangoes. *Food Packag Shelf Life.* 2025; 52:101638.
56. Zhao J, Pan L, Zhou M, Yang Z, Meng Y, Zhang X. Comparative physiological and transcriptomic analyses reveal mechanisms of improved osmotic stress tolerance in annual ryegrass by exogenous chitosan. *Genes (Basel).* 2019;10(11):853.

Figures

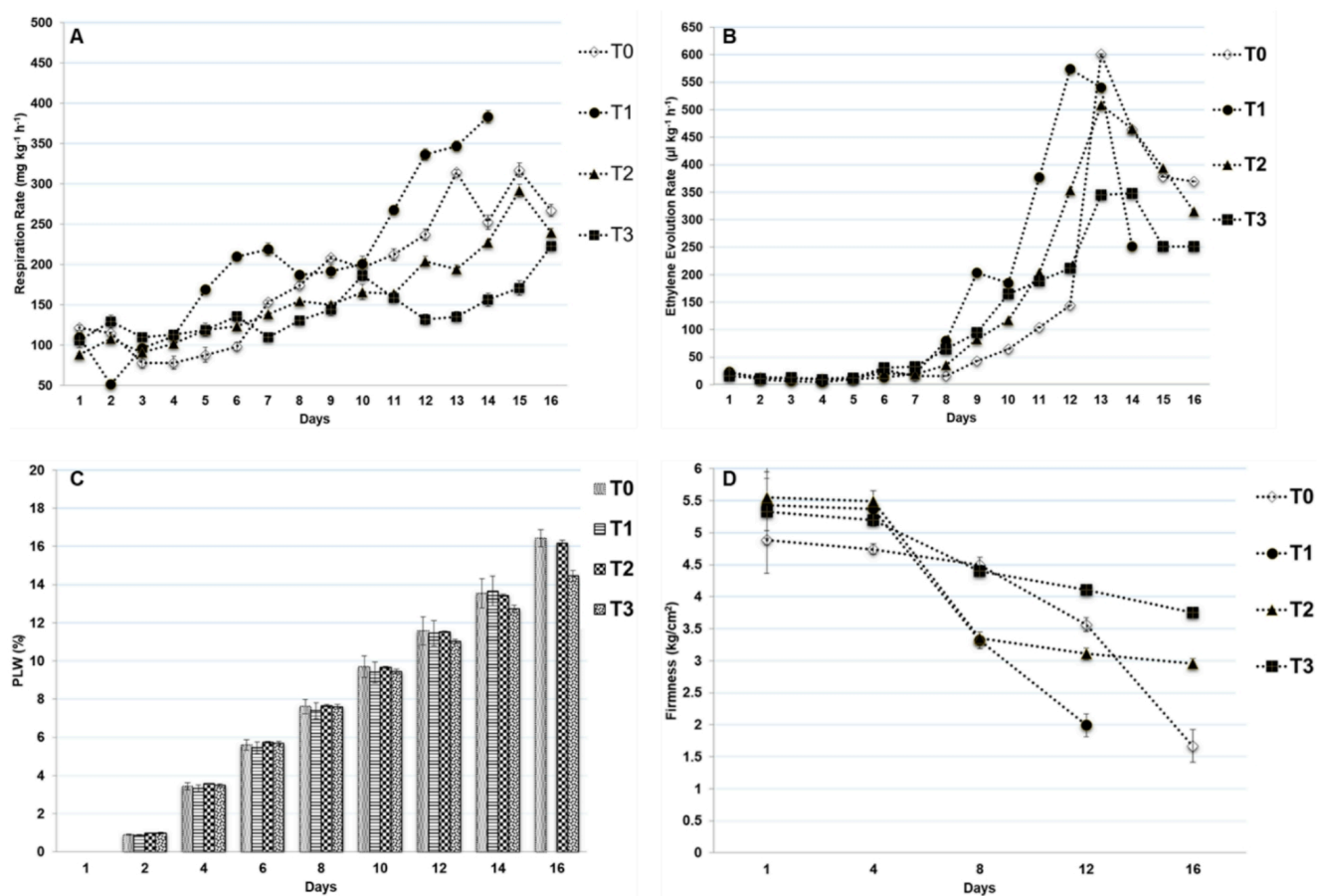


Figure 1

Effect of chitosan coating on the respiration rate (A), the ethylene evolution rate (B), PLW % (C) and Firmness (D) of the off-season mango cv. 'Rumani'.

Note: * Chitosan 0.5% treated fruits have spoiled on 14th day, thereby no readings were taken further.

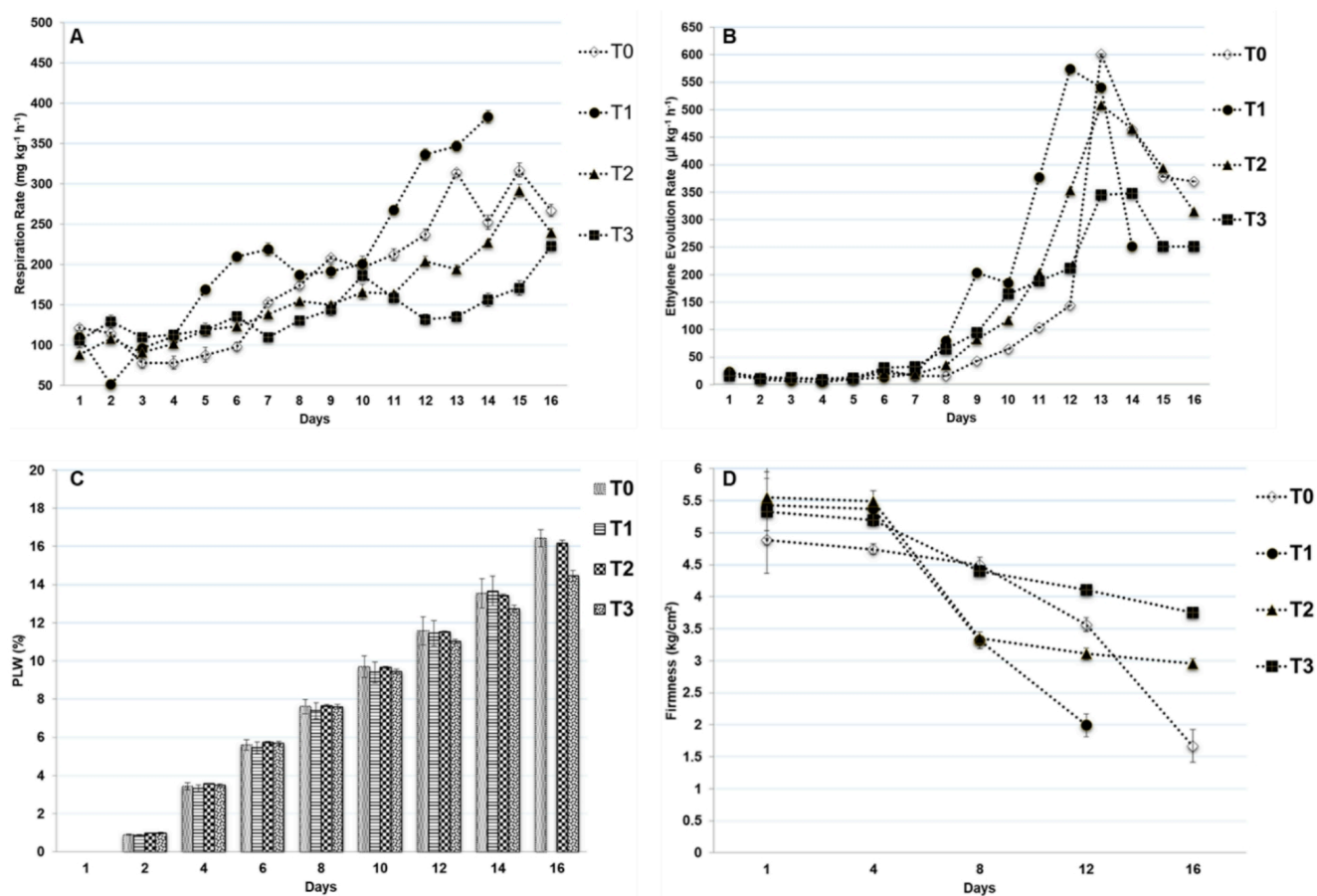


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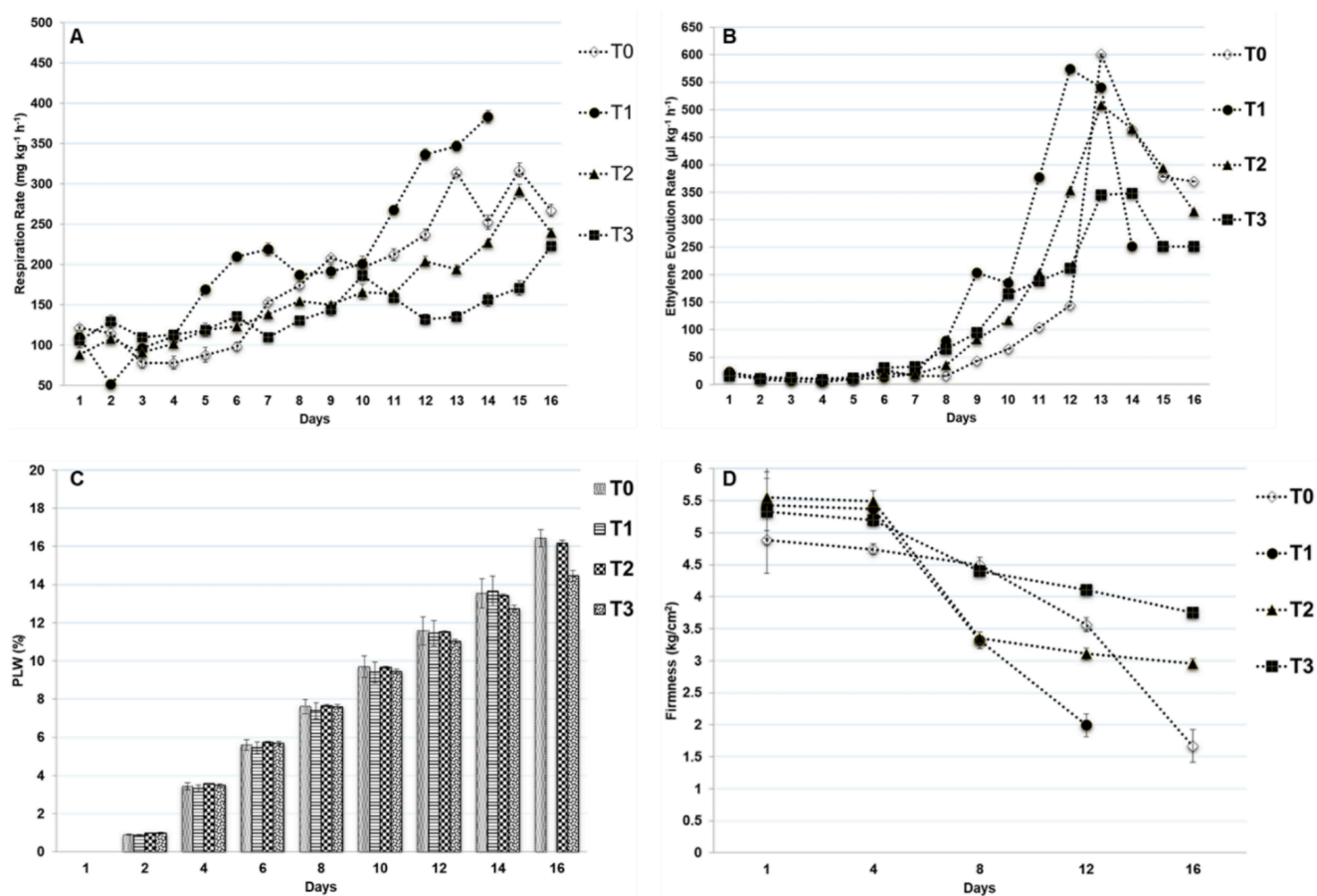


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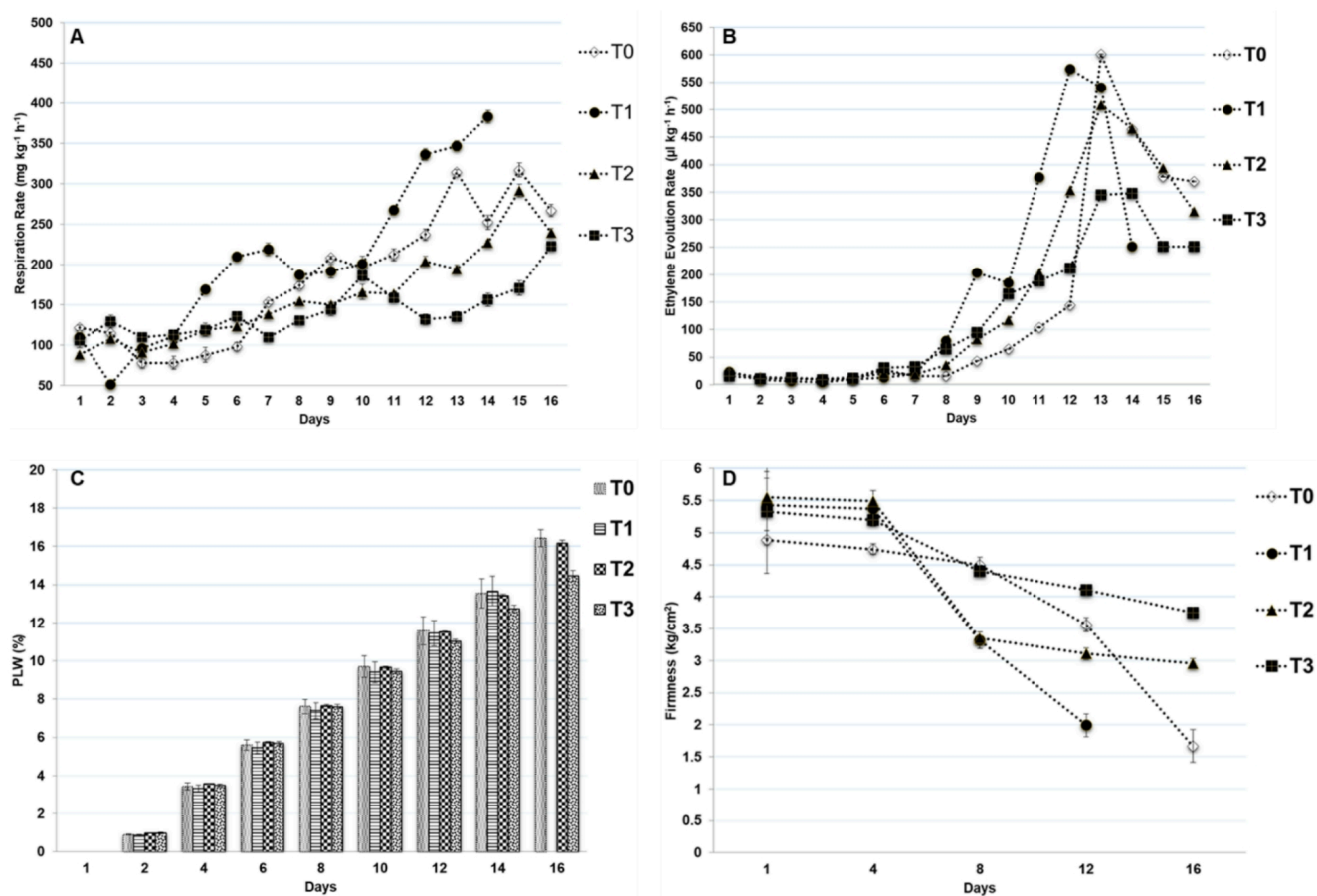


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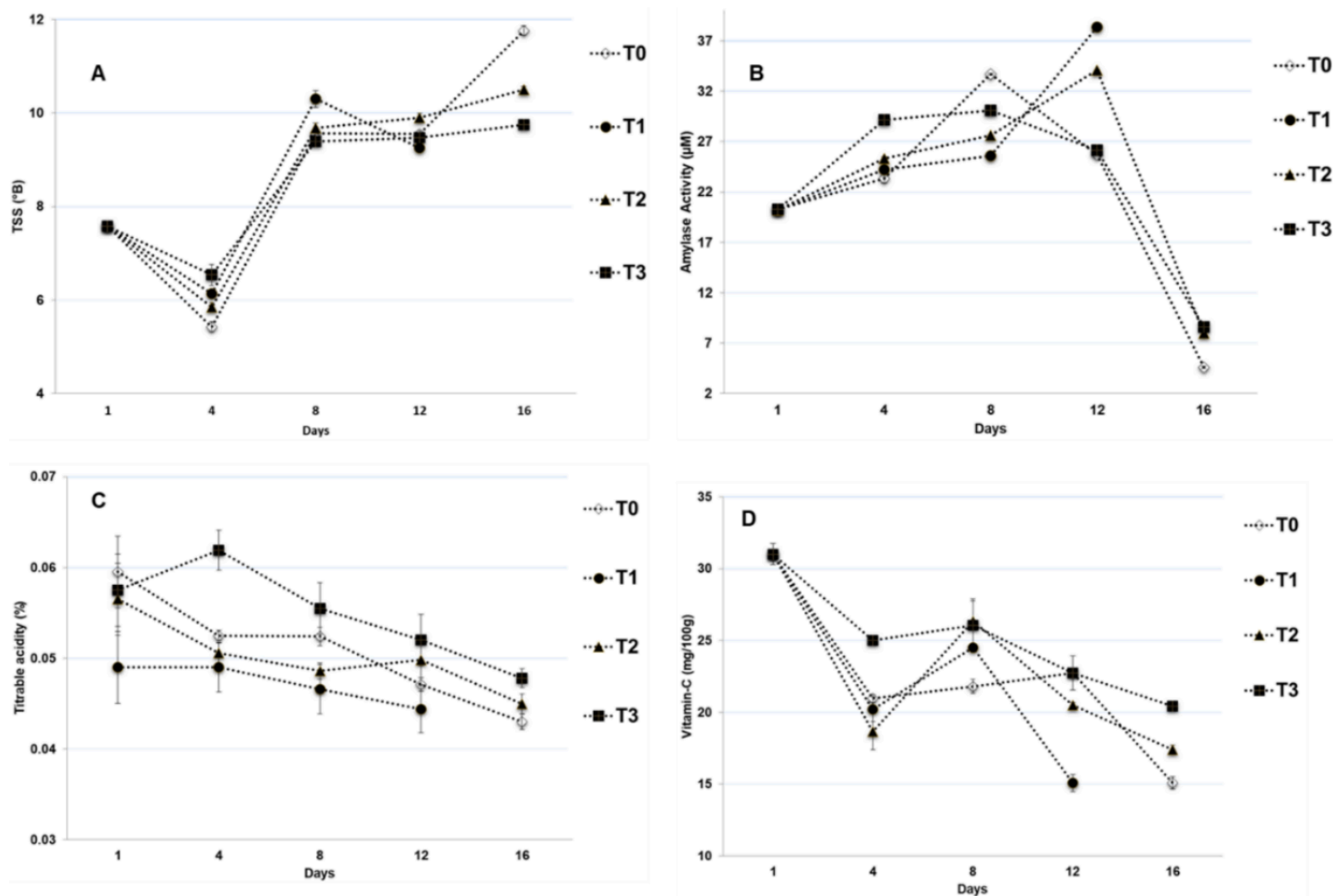


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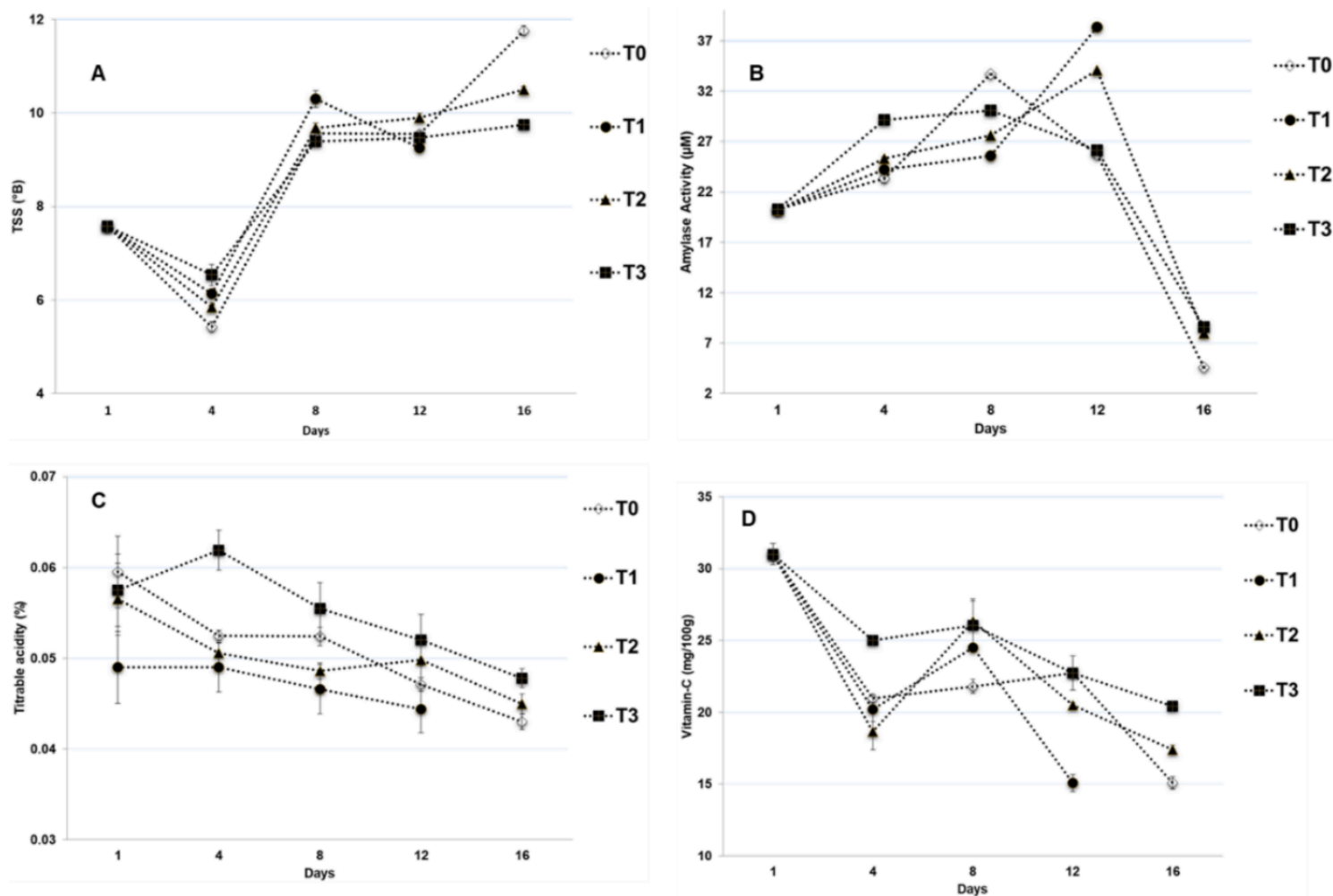


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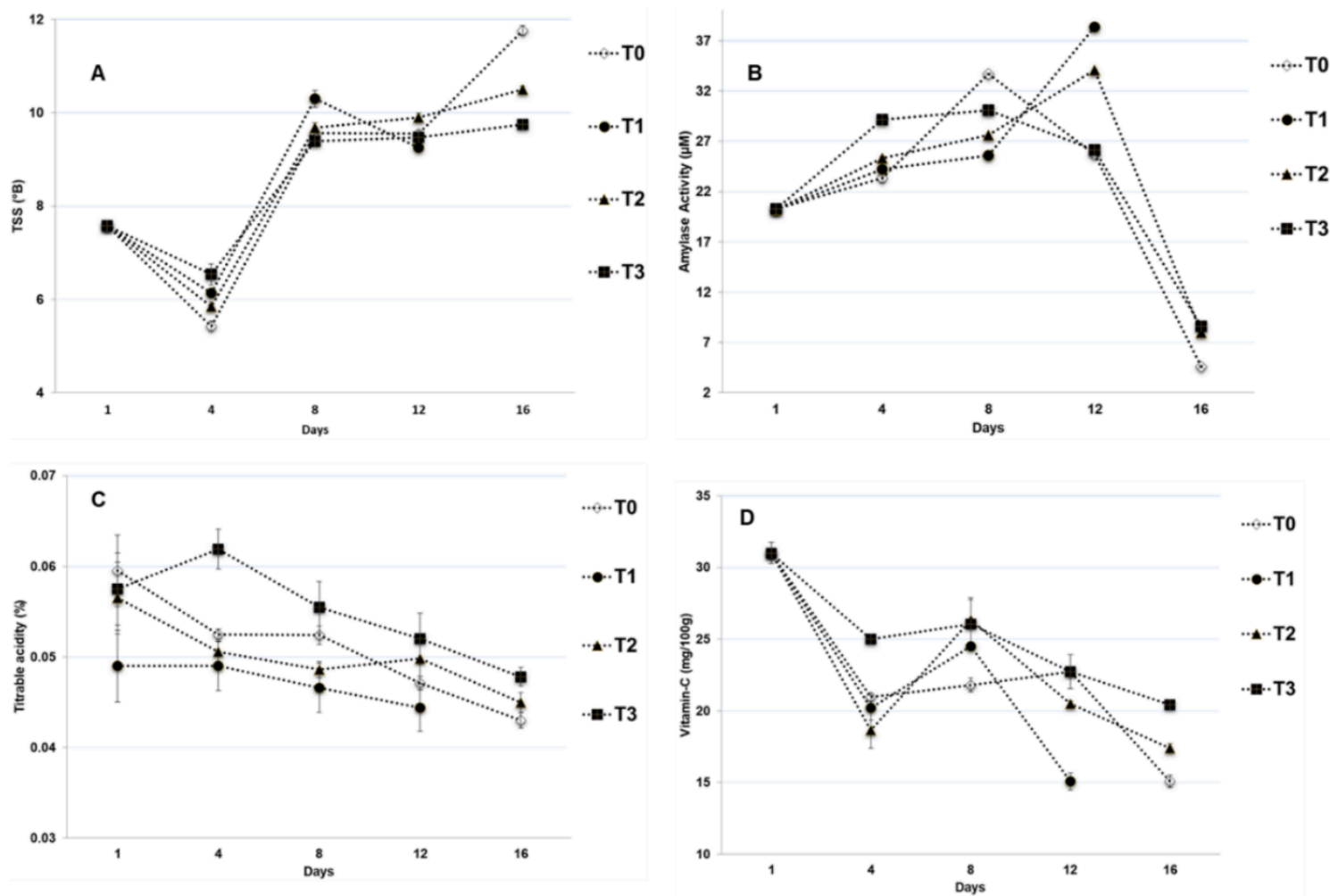


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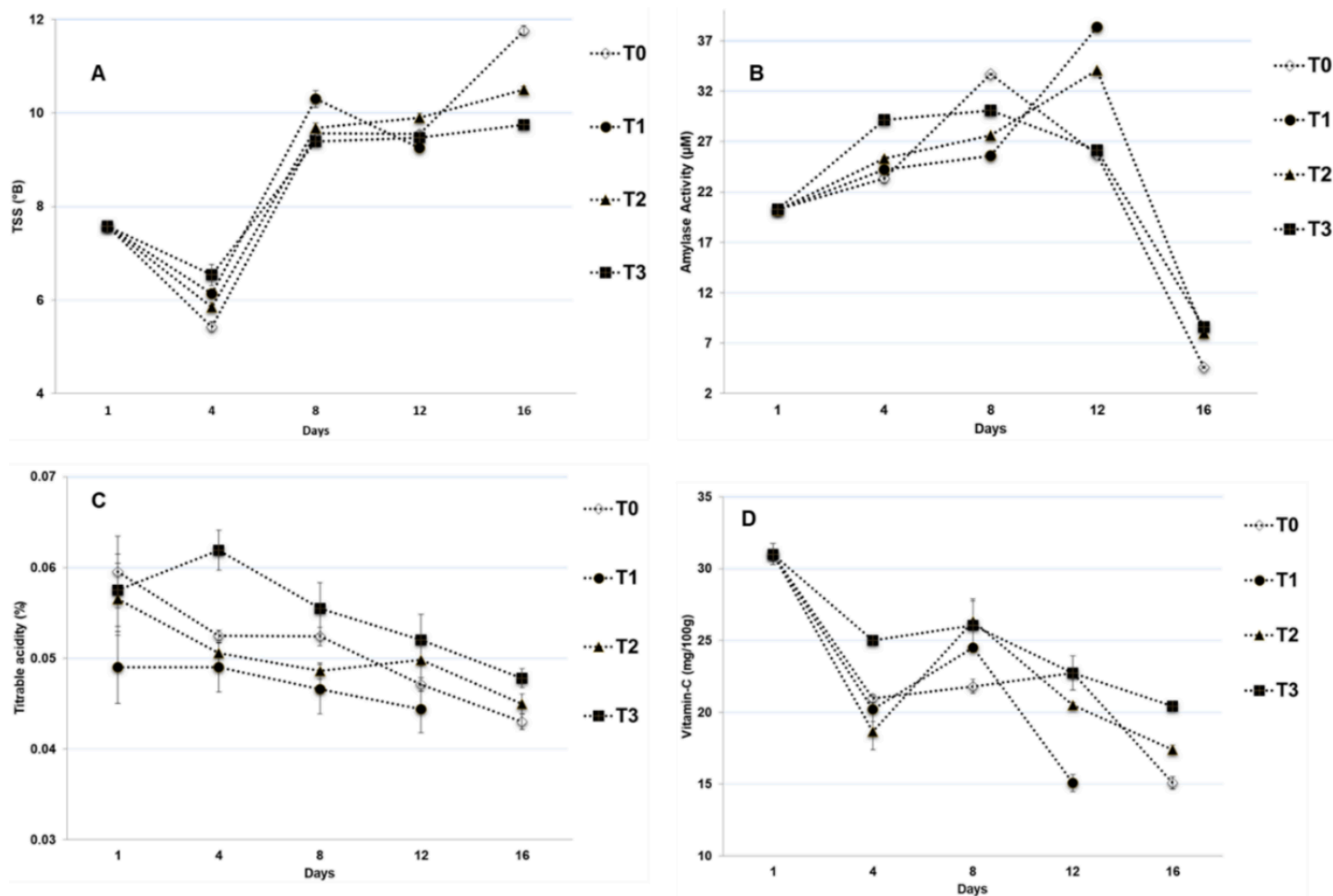


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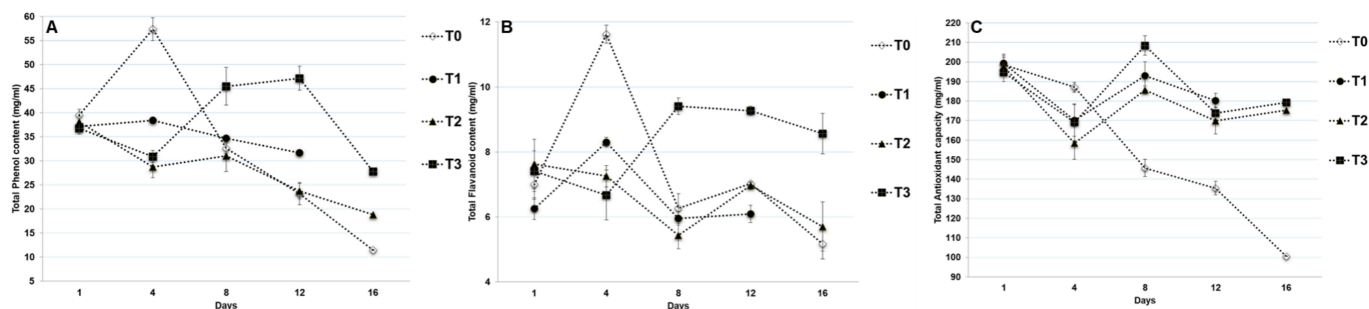


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Effect of chitosan coating on the total phenol content (A), the total flavonoid content (B) and the total anti-oxidants content (C) of the off-season mango cv. 'Rumani'.

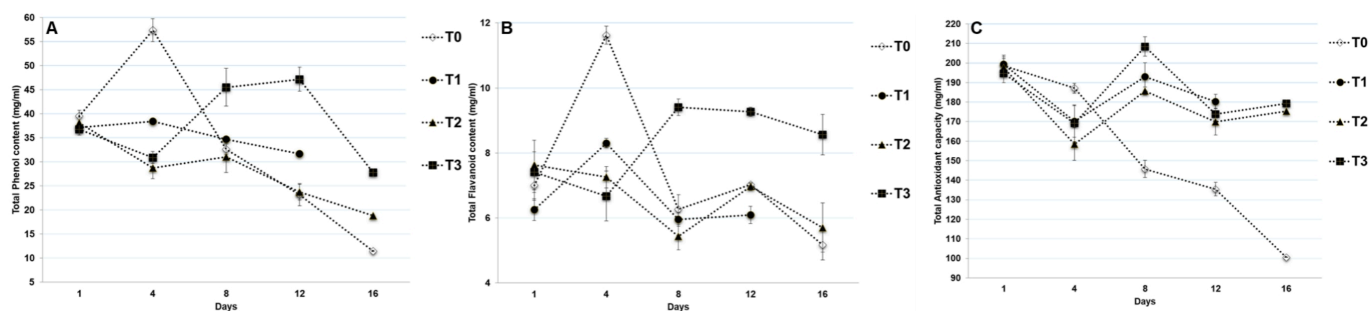


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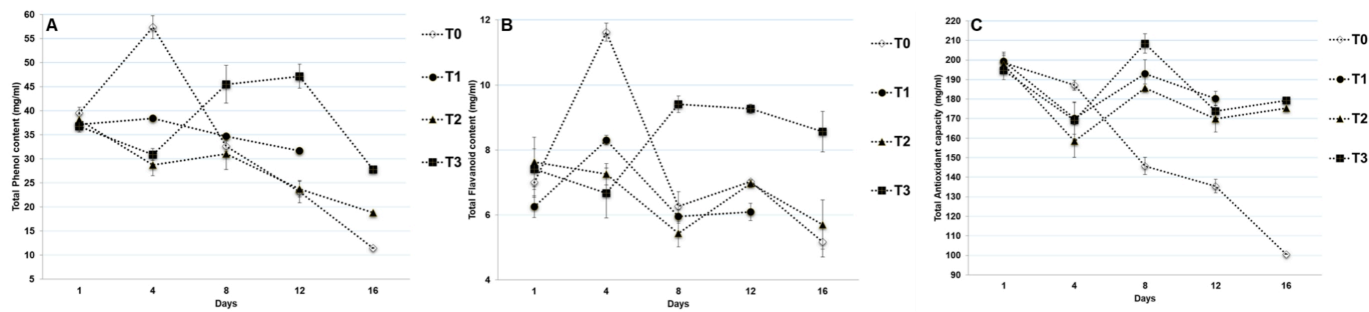


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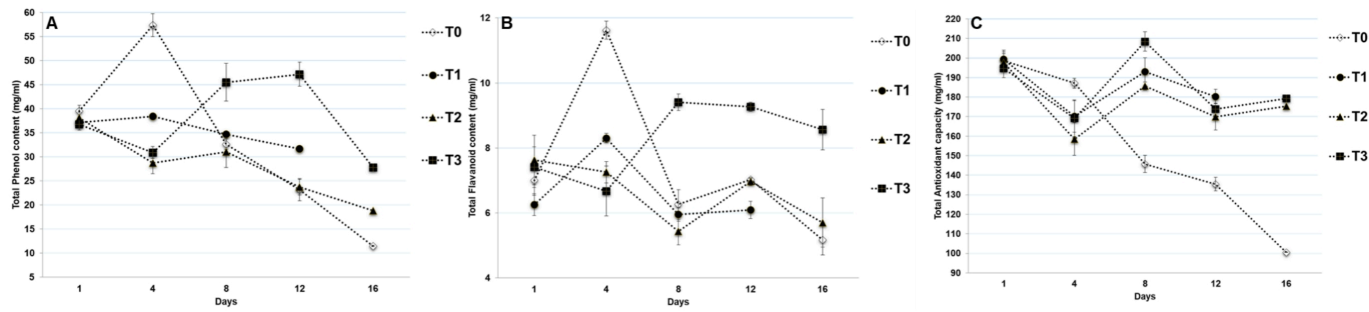


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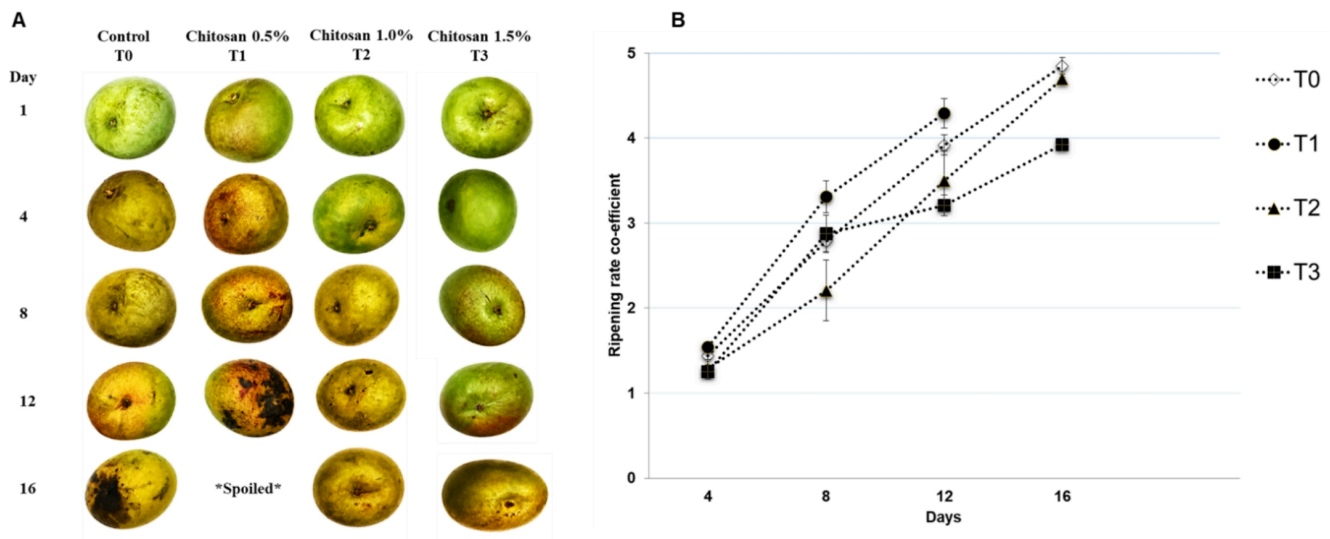


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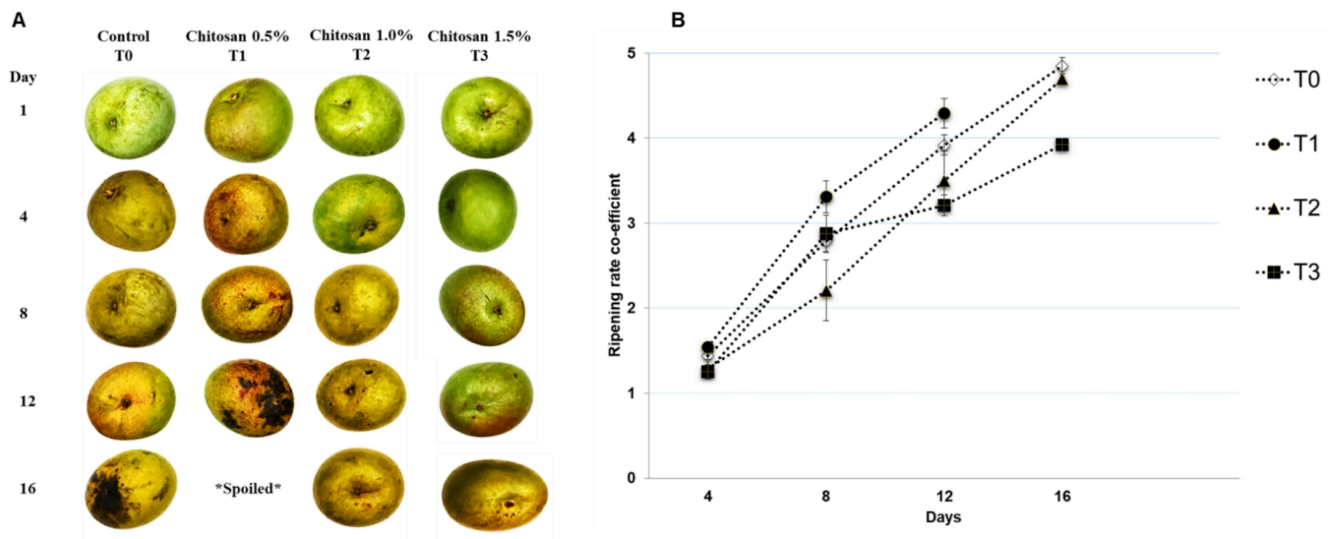


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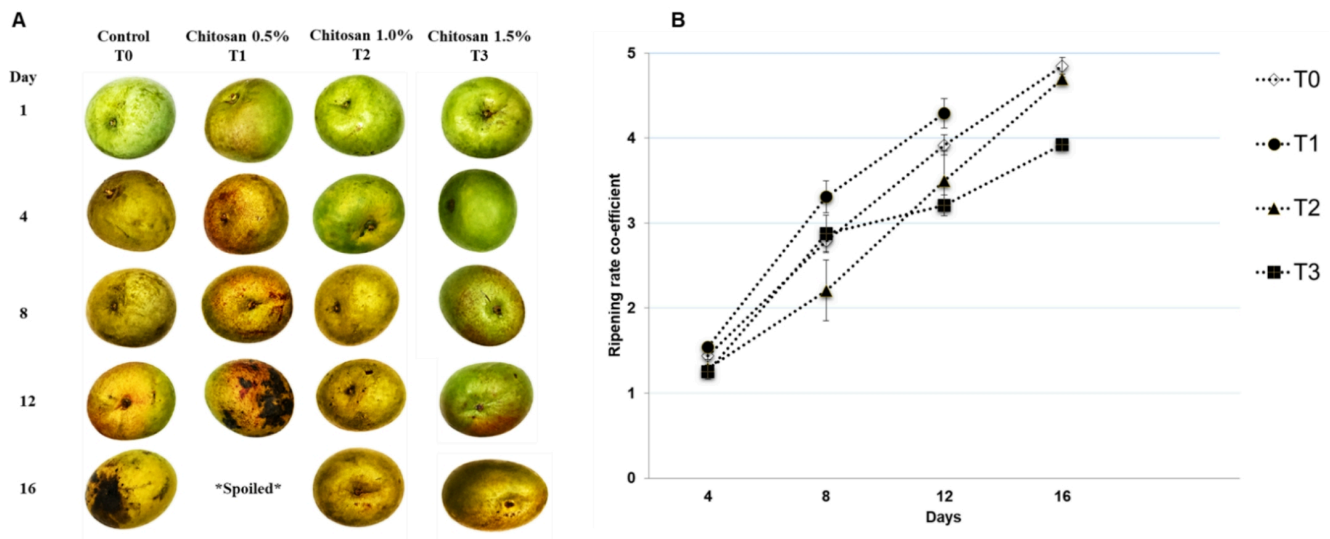


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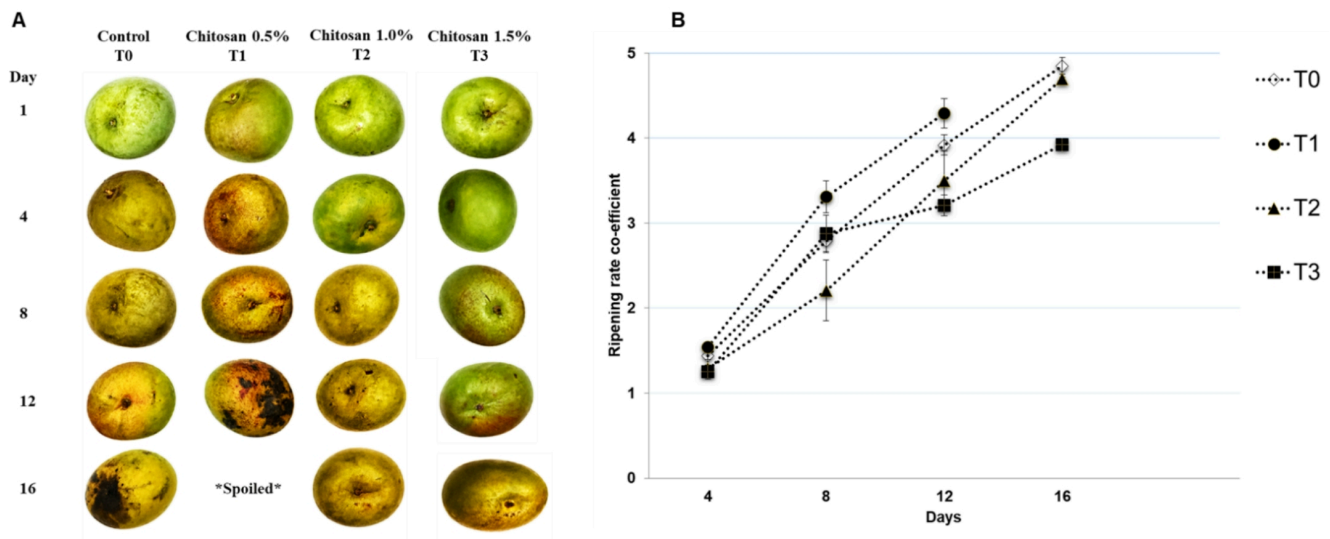


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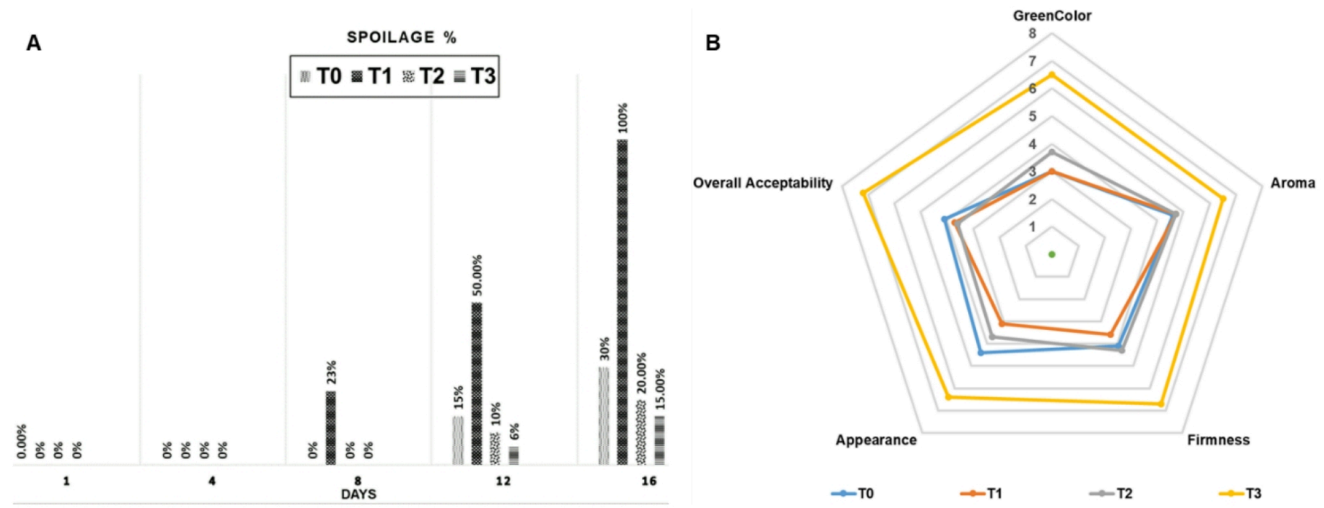


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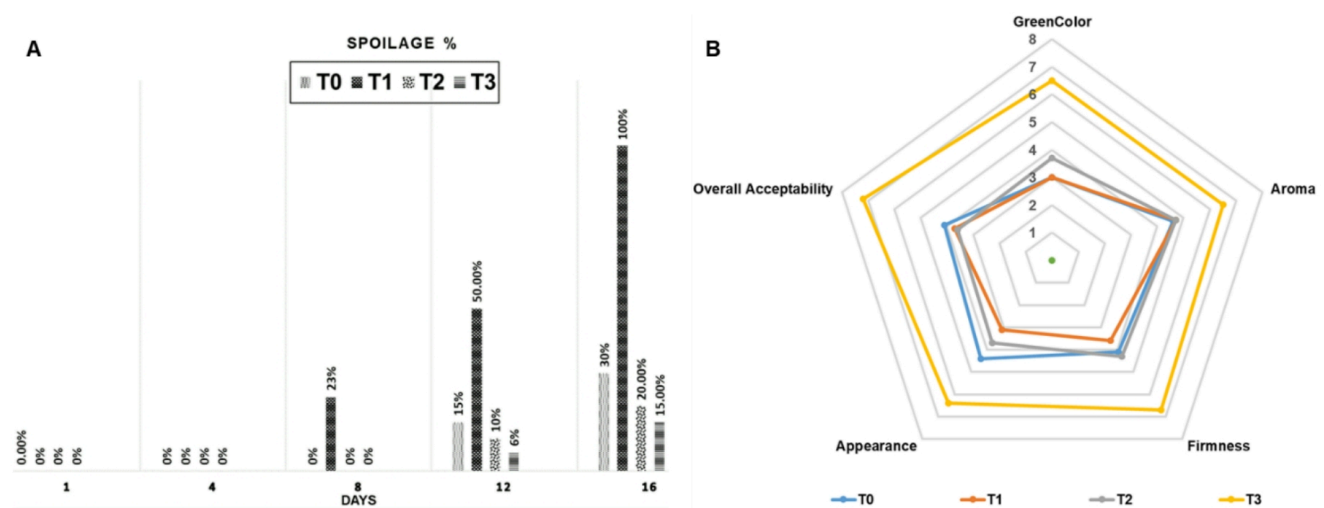


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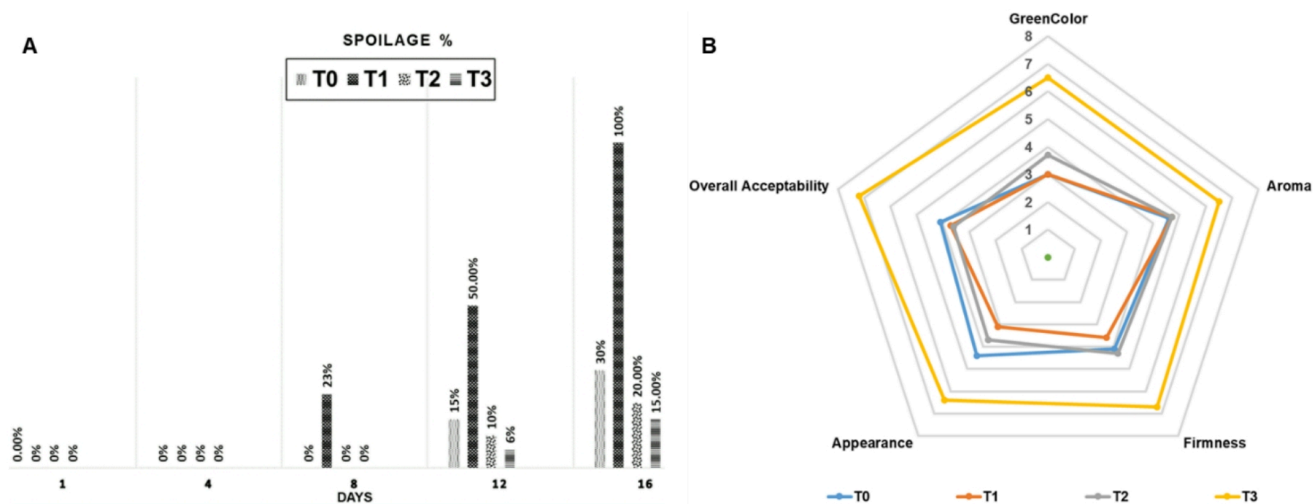


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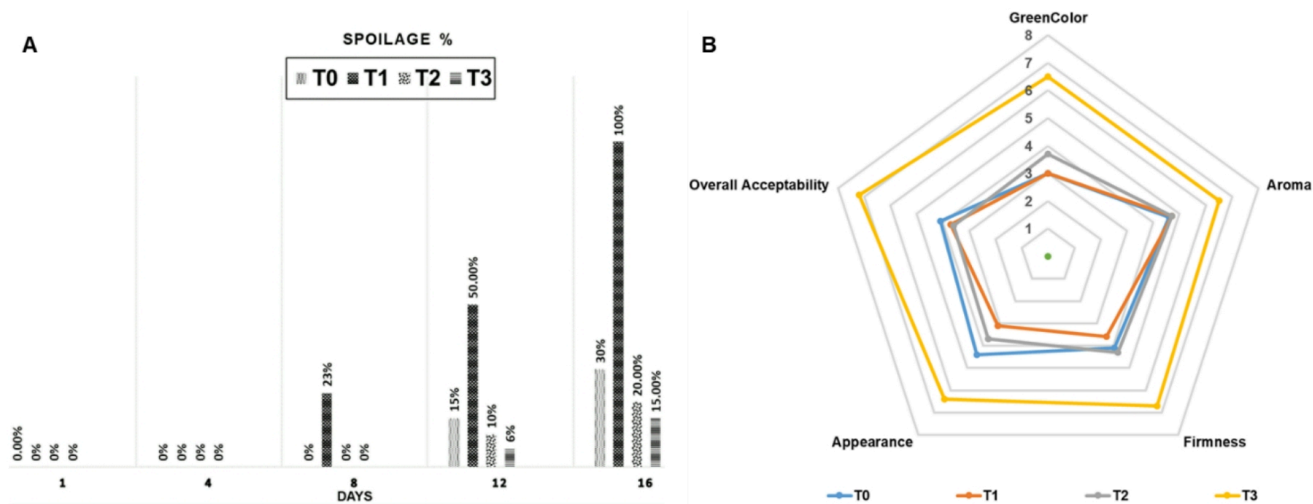


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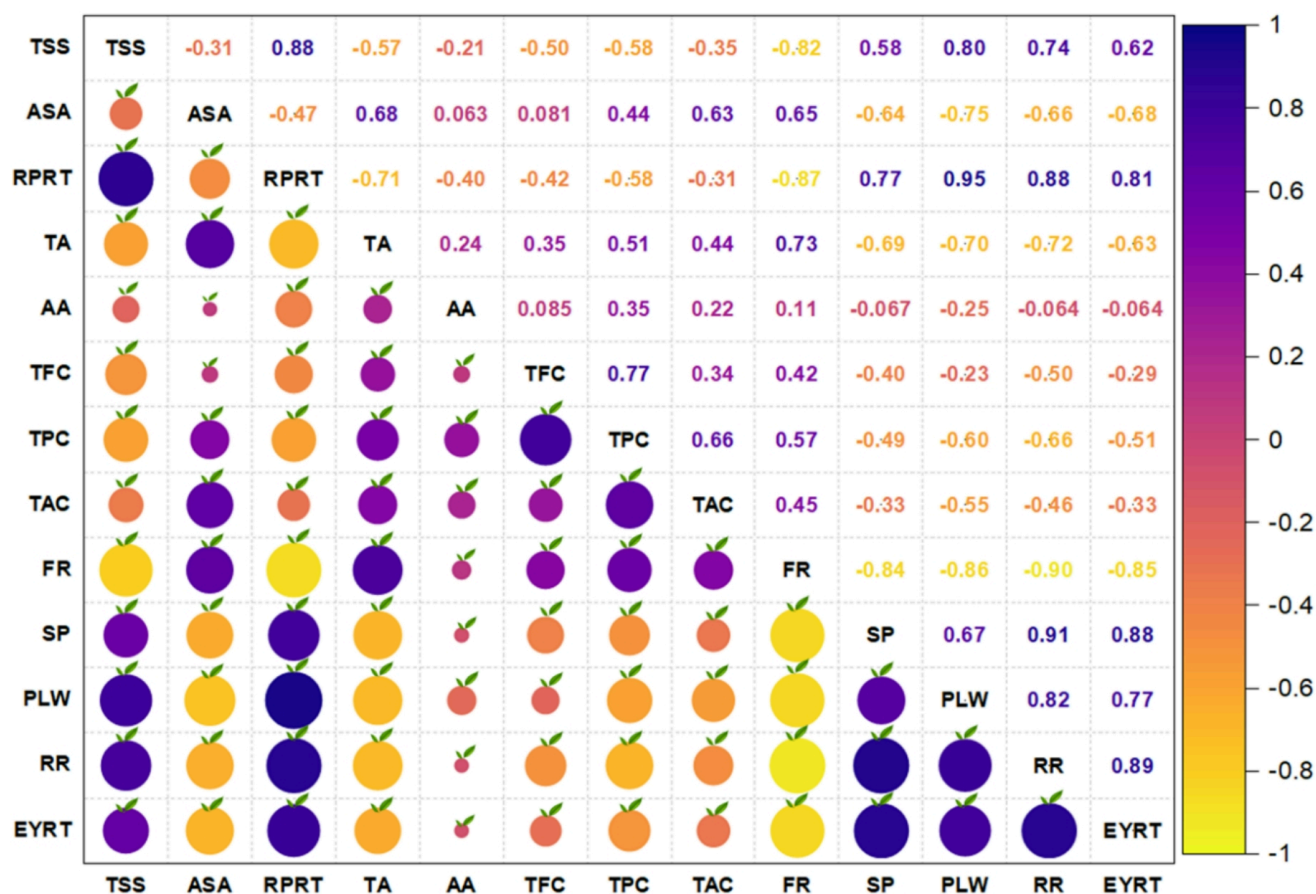


Figure 6

Correlation analysis depicted in the form of a correlogram of all physical, biochemical, nutritional, and visual parameters of the off-season mango cv. 'Rumani'. The strength of the correlation is represented by the colour intensity: Deep indigo (positive) to Bright yellow (negative). r = correlation coefficient. The shades of colour, from deep indigo to bright yellow, indicate correlation values from +1 to -1.

Abbreviations: TSS: total soluble solids, ASA: ascorbic acid, RPRT: respiration rate, TA: titrable acidity, AA: α -amylase activity, TFC: total flavonoid content, TPC: total phenol content, TAC: total antioxidant capacity, FR: firmness, SP: spoilage percentage, PLW: physiological loss in weight, RR: ripening rate coefficient, EYRT: ethylene evolution rate.

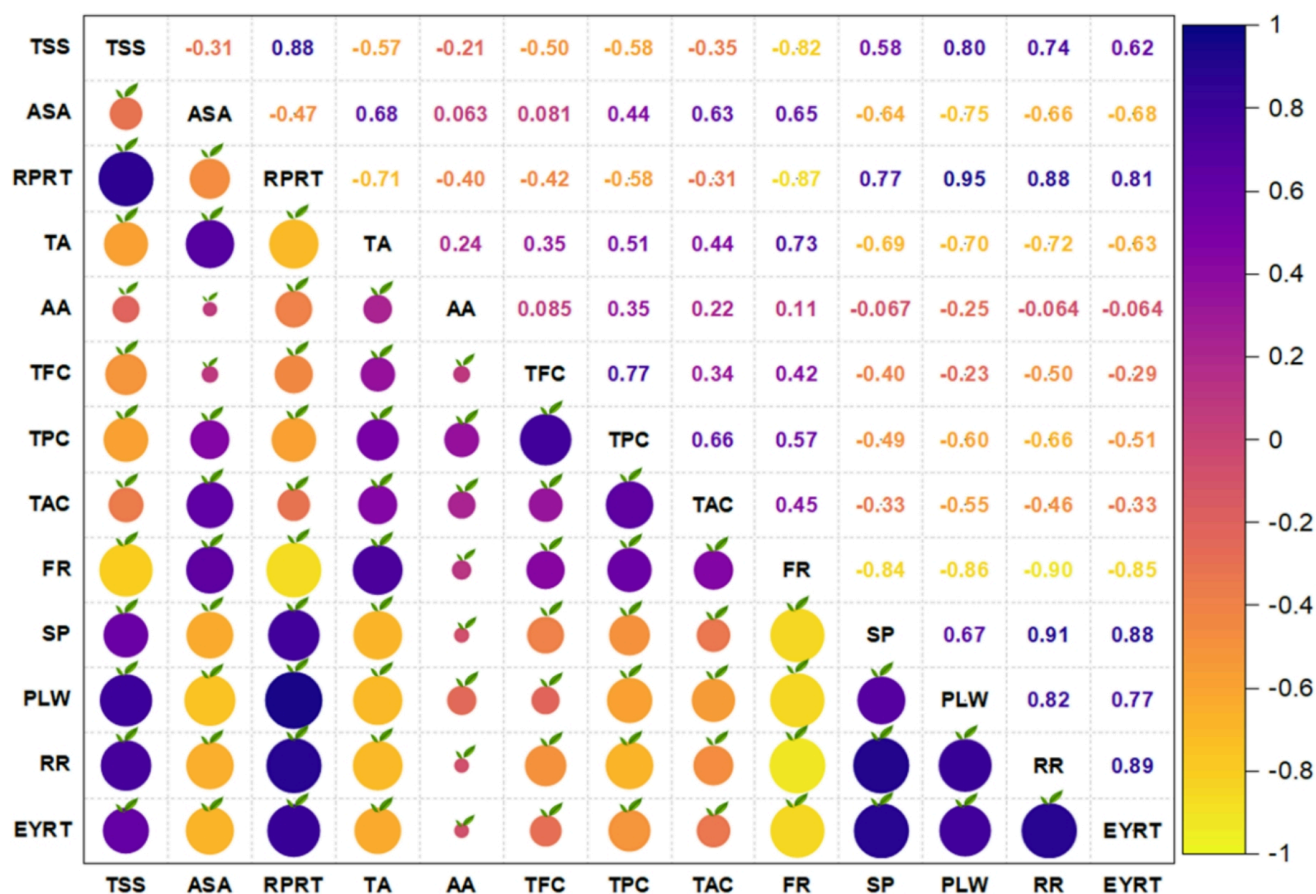


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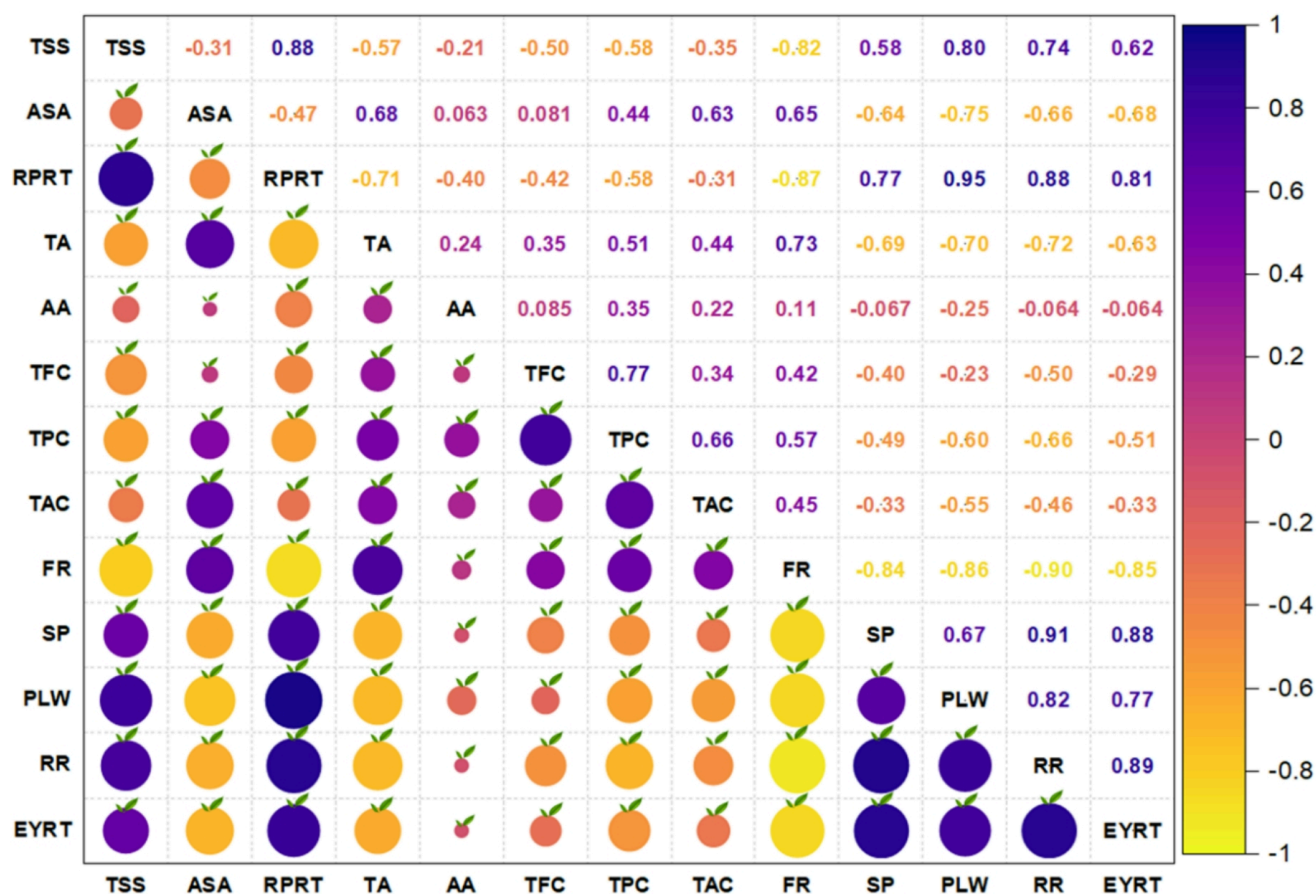


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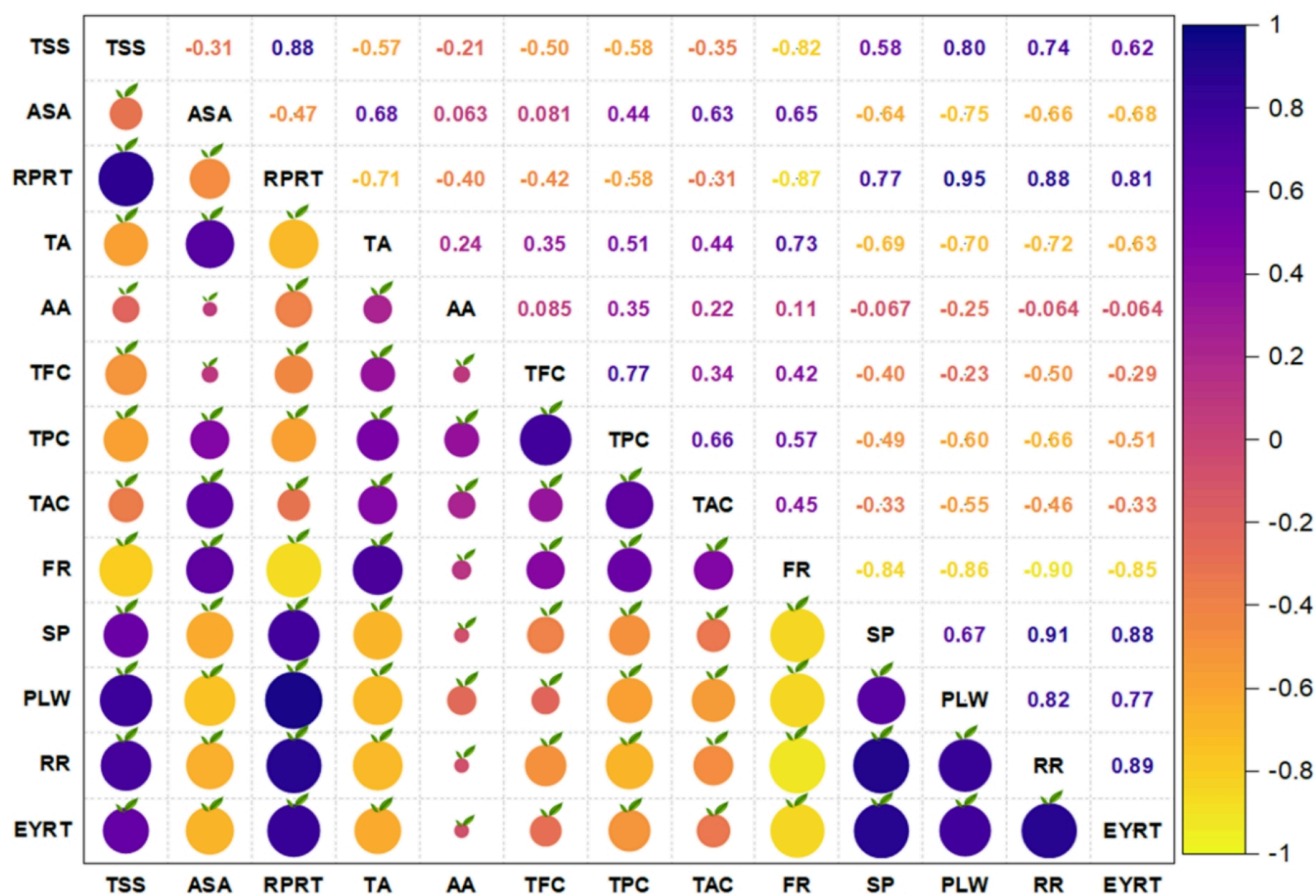


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