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**REGULAR ARTICLE**

# Texture quality of tomatoes as affected by different storage temperatures and growth habit

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## Abstract

The pericarp firmness and overall fruit firmness of different in growth habit tomatoes were investigated during ripening and storage in order to determine the texture changes as affected by the temperature. The study was carried out with eight tomato varieties. Mature-breaker tomato fruits were ripened at 12°C (chilled) and at 18-22°C (non-chilled). After postharvest ripening the chilled fruits were stored at 1°C and 6°C and non-chilled – under the ripening temperature. All tomato fruits were stored up to 7% loss of water content. The regression analysis showed that pericarp and fruit firmness decrease during the ripening and storage. This negative correlation between texture quality and storage time depended on both, used temperature and growth habit. The pericarp firmness of chilled tomatoes retained higher values compared with non-chilled. However, effects of the different temperatures on overall fruit firmness were not detected. The smallest texture changes were established for indeterminate large tomatoes at prolonged shelf life. Regression models for the texture changes were obtained, which are applied to determine the shelf-life at the relevant temperature.

*Key words*: Pericarp, Ripening, Temperature, Texture, Tomato, Shelf-life

## Introduction

The tomato texture, associated with their firmness is an important quality characteristic and essential in the consumer evaluation (Aked, 2002; Batu, 2004; Chaib et al., 2007). The tomato fruit firmness is a texture attribute characterized their storage ability and expresses deformation resistance (Wu and Abbott, 2002; Yurtly and Erdoğan, 2005).

The loss of freshness and softening of the tomato tissue is the result of turgor pressure loss and polysaccharides degradation in tomato fruit pericarp (Ealing, 1994; Femenia et al., 1998). Initially gradual softening of the tissues and subsequently taste deterioration are characteristic external symptoms which are due to respiratory rate and polysaccharide changes (Chiesa et al., 1998; Van der Valk and Donkers, 1994). As enzymatic processes, their rate during storage is under the influence of the pH value of raw material and the temperature (Spagna et al., 2005).

Among environmental factors temperature is reported to strongly affect tomato texture (Atta-Aly, 1992; Buffington and Sastry, 1983). The researches show greater decrease in fruit firmness throughout higher storage temperatures (Brackmann et al., 2007; YounSuk et al., 2008).

Since tomatoes are a perishable fruit and one of the most consumed in Bulgaria, it is important to know the physical properties associated with the tomato fruit ripening and storage to reduce their postharvest losses and achieve an extended storage period. Furthermore, little information is available concerning the interaction of temperature and growth habit on the tomato firmness during ripening. Thus, a more comprehensive study concerning the effects of different temperatures and growth habit on shelf life is needed.

The objective of the study was to assess the impacts of ripening temperatures and growth habit on tomato texture. Assessment is based on their effects on pericarp firmness and overall fruit firmness.

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## Materials and Methods

### Raw materials

The investigation was carried out with eight tomato varieties, classified by growth habit in three groups: determinate tomatoes – Joker $F_1$ (VILMORIN), Townsville $F_1$ (Bejo Zaden) and Nikolina $F_1$ (Agrogid) as standard; indeterminate tomatoes – Belladona $F_1$ (Seminis), Majestic $F_1$ (Nickerson-Zwaan) and Rila $F_1$ (Geosem) as standard; and indeterminate cherry tomatoes – IZK Alya and breeding line 1475 (Maritsa Vegetable Crops Research Institute, Bulgaria). The plants were cultivated in Maritsa Vegetable Crops Research Institute in Plovdiv applying the commonly accepted in Bulgaria technology for late crop open field tomato breeding.

### Experimental design

Tomatoes were harvested in mature-breaker stage according to the European standard for maturity. The harvesting and primary handling were carried out in two consecutive days, thus ensuring homogenous initial status of the fruit prior to storage. The fruits were packaged into crates in one layer with stem pit up. The six test batches of each tomato variety for each of the temperatures were stored in experimental chambers with and without air cooling. The storage of tomatoes started with the induction of ripening process at 12°C and 18-22°C. Having reached the red maturity, the tomatoes ripened at 12°C were transferred for further storage at 1°C and 6°C.

### Texture measurements

The texture changes during storage were analyzed by TEXTURE ANALYSER TA.XT_plus (Stable Micro Systems Ltd., UK), with 50 kg load cell of the randomized samples of 20 fruit in red maturity.

Pericarp firmness (±SD) was defined as a linear regression obtained during testing of tomato fruit, measured at 6 locations in equatorial diameter of 10 tomato samples using a P45C Cone 45° probe in the penetration depth 5mm (TA Application Guide);

Fruit firmness (±SD), the integral value of all efforts during 0 to τ, sec, was expressed as deformation work obtained from penetration test, measured for the other 10 tomato fruits using a P/5 Cylindric probe 5mm and penetration depth to the fruit center. Measurement was made at four sites evenly distributed along the tomatoes equatorial diameter (TA Application Guide).

The regression analysis for pericarp firmness changes (N/mm) and the deformation work (MPa.mm) for fruit texture changes were performed for each tomato variety every 2 weeks of the storage. The obtained results were averaged and used for further analyses. The established texture storage time trends were approximated by linear regression and equations were worked out for each variety. The impact of ripening temperature and following storage temperature on the fruit texture of each variety was determined by exponential dependences.

### Statistical analysis

The linear regression for pericarp firmness (Figure 1) and deformation work for fruit firmness (Figure 2) were calculated using Stable Micro Systems software (TEXTURE EXPONENT). The statistical process for estimating the relationships at $R^2$>0.75 between texture changes and both, storage time and temperature were performed using analysis tools of Excel.

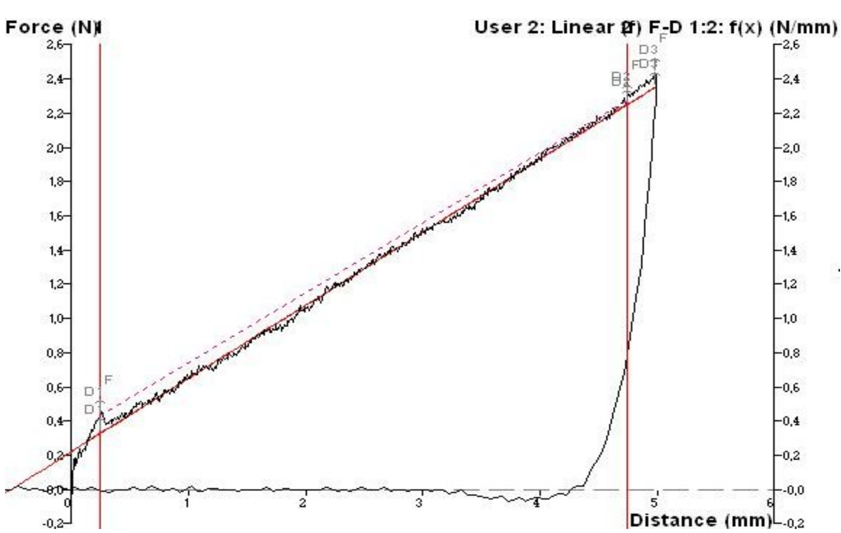



Figure 1. Typical curve obtained by testing the pericarp firmness of each tomato variety stored at 1°C, 6°C, and 18-22°C. The slope indicates calculated linear regression (N/mm).

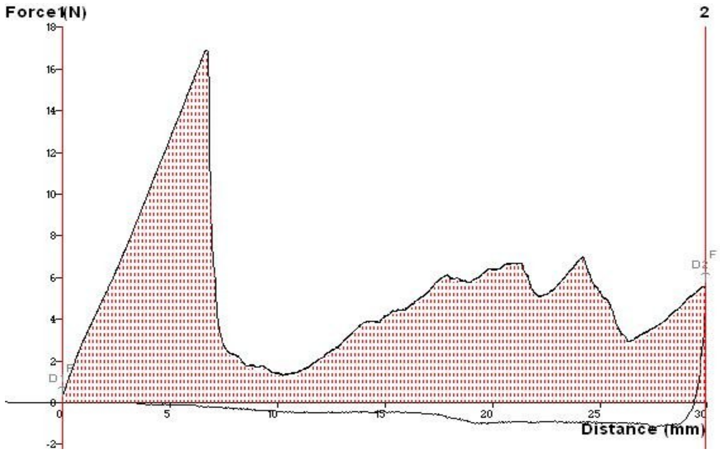



Figure 2. Typical curve obtained by testing the fruit firmness of each tomato variety stored at 1°C, 6°C, and 18-22°C. The shaded area indicates calculated pressure per unit area (MPa.mm).

## Results and Discussion

Examples of the linear curves obtained on the base Figures 1 and 2 are plotted in Figure 3, and the linear regression models for each variety and storage temperature are shown in Table 1. The impacts of ripening and following storage temperatures on the tomato texture of each variety are plotted in Figure 4.

There was negative correlation between fruit texture quality and storage time (Figure 3, Table 1). Such a result agrees with the ones found in the literature. Postharvest decreases in tomato firmness have been reported regardless of the methods used to maintain the postharvest quality (Aked, 2002; Femenia et al., 1998).

On the analogy of the mature-red fruit storage, tomato shelf-life at ripening is genetically determined (Brackmann et al., 2007). So after ripening of the chilled tomatoes and storage at 1°C the indeterminate, the determinate and the indeterminate cherry tomatoes are clearly distinguished. The difference between the tomato growth habits is outlined when ripening conditions are the same, but the storage is continued at 6°C. Chiesa et al. (1998) reported that firmness of tomatoes was related to the storage temperature and type of hybrid. This is probably the reason the variety Joker is an exception. Its storage period is equal with indeterminate varieties at similar firmness value. Therefore, on the tomatoes Majestic and on the tomatoes Joker might be given priority when ripened at 12°C and then stored at 1°C. The comparison between the cherry tomato varieties shows less texture change in tomatoes IZK Alya. The tomatoes Joker and especially the tomatoes Majestic preserve texture better in the other case, when tomatoes ripened chilled and stored at 6°C. Their firmness changes are similar to the other large-fruit varieties, but extended by two weeks storage period. The cherry tomatoes show reduced, but twice bigger firmness for tomatoes IZK Alya at the end of storage under these conditions. The smallest texture changes are determined for tomatoes Joker, Belladona and Majestic at 18-22°C with prolonged the term compared to the other varieties. Their firmness values are similar to Townsville and Nikolina, but after four weeks of storage. The cherry varieties firmness values are close to each other under these conditions.

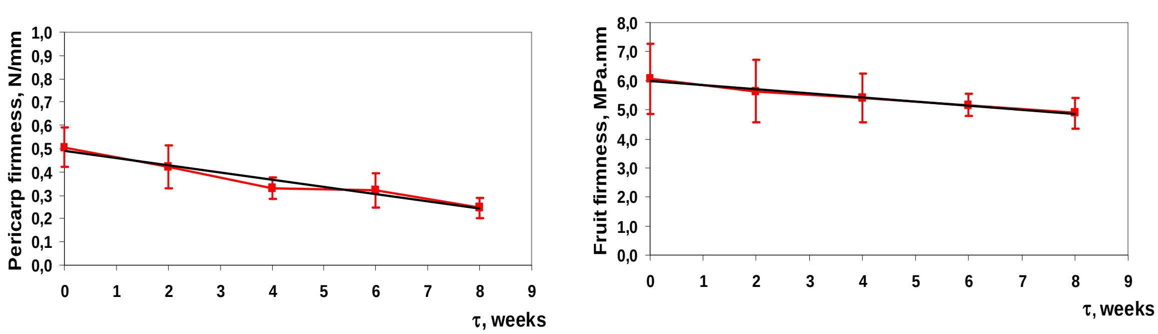
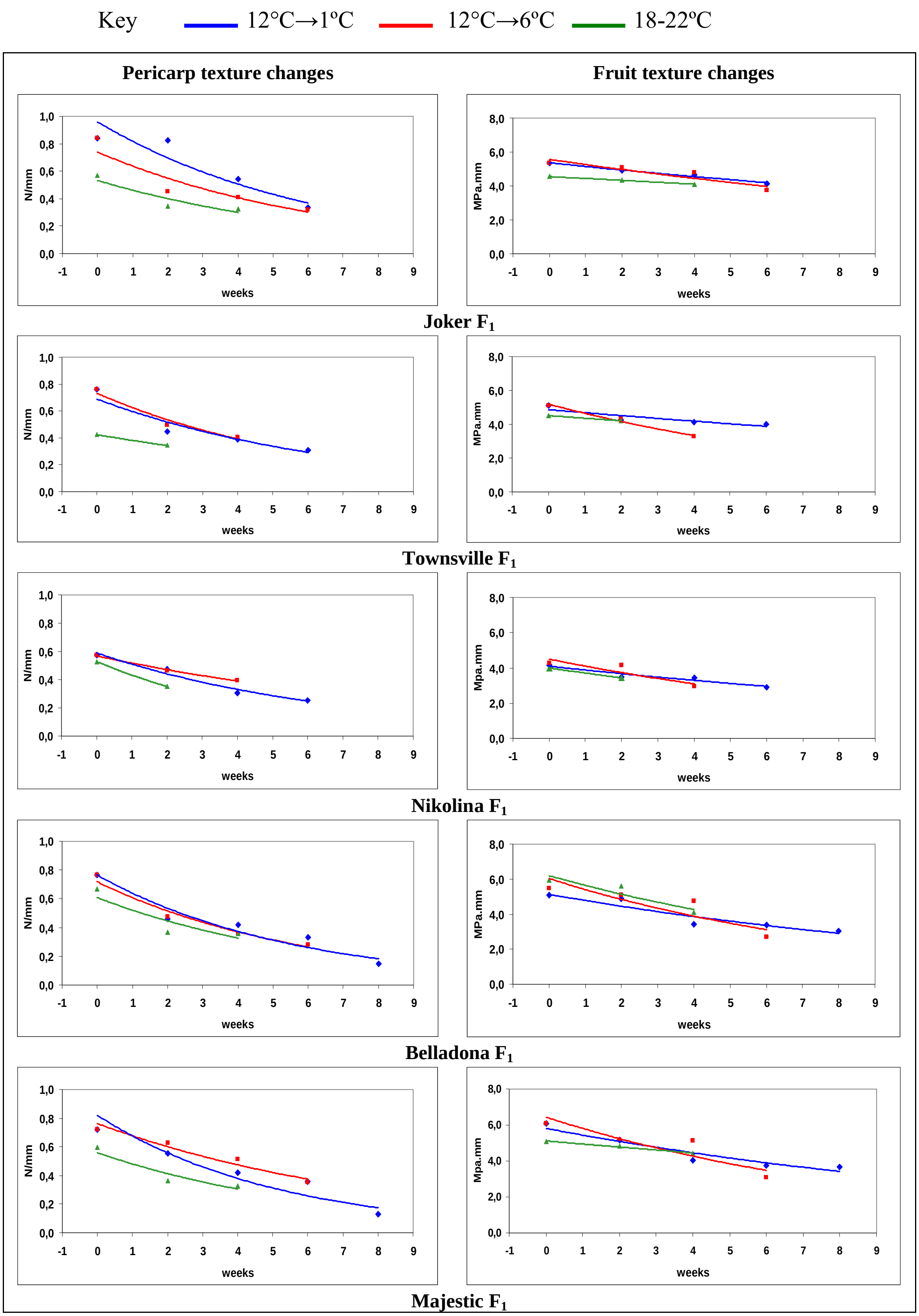



Figure 3. Examples of linear curves obtained for texture changes as a function of storage time for each tomato variety. Vertical bars indicate standard deviations.

Table 1. Linear regression models for texture changes $F = f(\tau)$ of each tomato variety ripened and stored at 1°C, 6°C, and 18-22°C as a function of storage time.

| Variety | $\tau$, weeks | $F_{pericarp}$, N/mm | $F_{fruit}$, MPa.mm |
|---|---|---|---|
| | | Ripening at 12°C and storage at 1°C | |
| Joker $F_1$ | 6 | y = -0.0901x + 0.9051<br>$R^2$ = 0.9108 | y = -0.1940x + 5.3427<br>$R^2$ = 0.9791 |
| Townsville $F_1$ | 6 | y = -0.0705x + 0.6869<br>$R^2$ = 0.8541 | y = -0.1713x + 4.8794<br>$R^2$ = 0.7912 |
| Nikolina $F_1$ | 6 | y = -0.0564x + 0.5720<br>$R^2$ = 0.9662 | y = -0.1907x + 4.0756<br>$R^2$ = 0.9220 |
| Belladona $F_1$ | 8 | y = -0.0678x + 0.6951<br>$R^2$ = 0.9183 | y = -0.2829x + 5.0853<br>$R^2$ = 0.8703 |
| Majestic $F_1$ | 8 | y = -0.0690x + 0.7125<br>$R^2$ = 0.9743 | y = -0.3118x + 5.7931<br>$R^2$ = 0.8830 |
| Rila $F_1$ | 8 | y = -0.0441x + 0.4537<br>$R^2$ = 0.9824 | y = -0.3627x + 4.3323<br>$R^2$ = 0.9329 |
| IZK Alya | 4 | y = -0.0537x + 0.4465<br>$R^2$ = 0.8795 | y = -0.3618x + 3.3151<br>$R^2$ = 0.9329 |
| Breeding line 1475 | 4 | y = -0.0164x + 0.1985<br>$R^2$ = 0.9836 | y = -0.2323x + 2.3047<br>$R^2$ = 0.9151 |
| | | Ripening at 12°C and storage at 6°C | |
| Joker $F_1$ | 6 | y = -0.0798x + 0.7452<br>$R^2$ = 0.8135 | y = -0.2527x + 5.5003<br>$R^2$ = 0.8768 |
| Townsville $F_1$ | 4 | y = -0.0879x + 0.7297<br>$R^2$ = 0.9278 | y = -0.4551x + 5.1408<br>$R^2$ = 0.9924 |
| Nikolina $F_1$ | 4 | y = -0.0450x + 0.5666<br>$R^2$ = 0.9809 | y = -0.3307x + 4.4435<br>$R^2$ = 0.8018 |
| Belladona $F_1$ | 6 | y = -0.0786x + 0.7051<br>$R^2$ = 0.9156 | y = -0.4334x + 5.7953<br>$R^2$ = 0.8133 |
| Majestic $F_1$ | 6 | y = -0.0615x + 0.7374<br>$R^2$ = 0.9847 | y = -0.4547x + 6.2388<br>$R^2$ = 0.8530 |
| Rila $F_1$ | 6 | y = -0.0512x + 0.4629<br>$R^2$ = 0.9738 | y = -0.3487x + 4.1232<br>$R^2$ = 0.9388 |
| IZK Alya | 2 | N/A | N/A |
| Breeding line 1475 | 2 | N/A | N/A |
| | | Ripening and storage at 18-22°C | |
| Joker $F_1$ | 4 | y = -0.0623x + 0.5384<br>$R^2$ = 0.8254 | y = -0.1120x + 4.5522<br>$R^2$ = 0.9974 |
| Townsville $F_1$ | 2 | N/A | N/A |
| Nikolina $F_1$ | 2 | N/A | N/A |
| Belladona $F_1$ | 4 | y = -0.0771x + 0.6198<br>$R^2$ = 0.7748 | y = -0.4639x + 6.1350<br>$R^2$ = 0.8845 |
| Majestic $F_1$ | 4 | y = -0.0675x + 0.5630<br>$R^2$ = 0.8578 | y = -0.1674x + 5.1166<br>$R^2$ = 0.9714 |
| Rila $F_1$ | 2 | N/A | N/A |
| IZK Alya | 2 | N/A | N/A |
| Breeding line 1475 | 2 | N/A | N/A |


Key
12°C→1°C
12°C→6°C
18-22°C
Pericarp texture changes
Fruit texture changes
N/mm
MPa.mm
Mpa.mm
weeks
Joker F1
Townsville F1
Nikolina F1
Belladona F1
Majestic F1

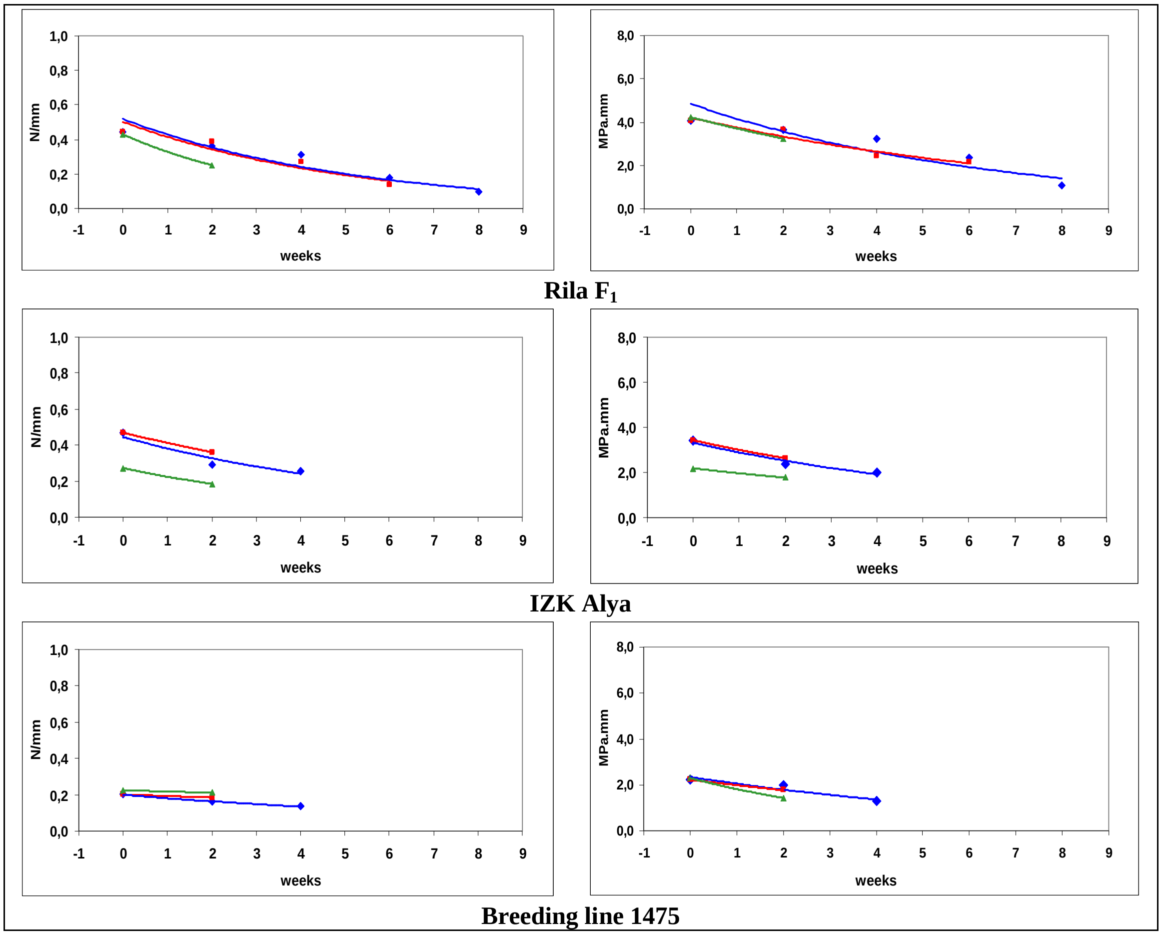



Figure 4. Pericarp and fruit texture changes as a function of ripening and storage temperatures for each tomato variety.

Distinctions between varieties in terms of the texture at different temperatures are established. The effect of the temperature is expressed on the changes in pericarp firmness (Figure 4). The trends in the pericarp firmness for each temperature are outlined for tomatoes Joker. The increased ripening temperature reduces the pericarp firmness in the non-chilled fruit for other varieties. Such an effect has been reported for tomato firmness throughout the storage at higher temperatures (Youn Suk et al., 2008). For the ripened chilled tomatoes, both cold storage temperatures extend the storage period, but changes in the pericarp texture have identical character. But, in this study, effect of temperature on the fruit firmness is not detected. The exceptions to these trends is IZK Alya, in this the higher temperature leads to a reduction in the fruit firmness.

## Conclusions

Our study indicated that the pericarp and overall fruit firmness of investigated tomato varieties decrease during the ripening and storage. Furthermore, this negative correlation between texture quality and storage time depended on both, storage temperature and growth habit. The pericarp firmness of chilled tomatoes retained higher values compared with non-chilled. Ripening at 12°C and following storage at 1°C and 6°C impact approximately equally of the pericarp firmness. However, effect of the different temperatures on fruit firmness was not detected. The smallest texture changes were established for indeterminate tomatoes. Linear regression models $F = f(\tau)$ for the texture changes were obtained, which are applied to determine the shelf life at the relevant temperature.

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