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Effects of climatic conditions on the physical and extensional properties of pomegranate fruit peel in Malas-e-Saveh and Yousefkhani cultivars

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ABSTRACT

Purpose: This research was carried out to investigate the physical and extensional properties of fruit peel in two commercially grown pomegranate cultivars across three distinct climatic conditions in Iran. **Research method**: Two pomegranate cultivars were examined in a factorial experiment in frame of completely randomized design across three producing regions, including Saveh, Sari, and Aliabad. **Findings**: The findings revealed that Yousefkhani had a higher crown diameter compared to Malas-e-Saveh. Among the regions studied, Saveh and Aliabad produced fruits with the highest and lowest fruit weight and percentage of membranous septum, respectively. Additionally, Sari and Aliabad, which have humid weather conditions, produced fruits with a lower crown diameter and membranous septum thickness compared to Saveh, which has dry weather conditions. Furthermore, the highest percentage of moisture in the fleshy mesocarp and peel and the lowest percentage of moisture in membranous septum were found in fruits cultivated in Sari and Aliabad, respectively. The results also showed that Malas-e-Saveh had the highest peel deformation in transversal oriented samples. Yousefkhani had a higher extension force compared to Malas-e-Saveh, while no significant difference was observed among regions or between the two sampling directions in these properties. **Research limitations**: None were found to report. **Originality/Value**: Based on the findings of this study, it can be concluded that most pomegranate fruit characteristics were significantly influenced by cultivar and growing region. Yousefkhani exhibited a thicker peel, a higher percentage of fleshy mesocarp, and greater tolerance to extension force compared to Malas-e-Saveh.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits and can grow in diverse agro-climatic conditions, ranging from tropical to sub-tropical regions (Zaouay et al., 2020). It is believed to have originated in Iran and central Asian countries (Ashrafi et al., 2023). The fruit develops from the ovary and is a fleshy berry (Singh et al., 2020). Pomegranate fruits are typically globular or somewhat flattened, with a diameter ranging from 5 to 12 cm, and are characterized by a thick tubular calyx. The calyx remains attached to the fruit until maturity, which is a distinguishing feature of pomegranates. The skin, peel, or exocarp of the fruit plays a vital role in supporting the internal cell layers. It serves as an essential component that provides a protective barrier against water loss and potential pathogen infiltration (Macnee et al., 2020). Within the fruit, the multiovule chambers (locules) are separated by membranous walls (septa) and fleshy mesocarp. The chambers are filled with many seeds (arils) and organized in a non-symmetrical way, with the lower part of the fruit containing 2 to 3 chambers, while the upper part typically includes 6 to 9 chambers (Holland et al., 2009).

In pomegranates, the occurrence of cracking can be attributed to variations in the growth rate between the fruit peel and flesh, as well as the pressure exerted by the rapidly expanding arils on the stretched peel (Ginzberg & Stern, 2019). Fruit cracking in pomegranates is primarily caused by deficiencies in nutrients such as calcium and boron during the early stages of fruit development, drastic fluctuations in day and night temperatures, irregular watering regimes during fruit ripening, and prolonged dry periods followed by heavy rains or irrigation (Galindo et al., 2014; Ghanbarpour et al., 2019; Fraschetti et al., 2023). Excessive water during the developmental stage is a prominent environmental stress factor that contributes to fruit cracking. This water excess can disrupt the balance of essential cations, such as calcium (Ca), which is crucial for maintaining the structural integrity of the fruit (Santos et al., 2023). Approximately 65% of the pomegranate cultivar Shishe-Kab experiences cracking (Hamedi Sarkomi et al., 2019). The mechanical properties of the cuticle can have both positive and negative effects on disorders such as fruit splitting, fungal pathogen penetration, and pest infestation (Dominguez et al., 2011). Additionally, changes in peel properties and fruit volume are believed to be involved in fruit cracking (Joshi et al., 2021). Saei et al. (2012) reported significant differences in many physical properties between resistant and sensitive cultivars to fruit cracking. Their results indicated that characteristics such as fruit volume, fruit shape, total arils weight, and peel weight/fruit weight had significant correlations with fruit cracking. Fruit cracking can also be attributed to environmental and nutritional factors, high-temperature daytime and nighttime travel, and the hardening of the fruit peel during a prolonged dry period, followed by a sudden expansion in the volume of the inner part of the fruit after rain or heavy irrigation (Fraschetti et al., 2023). Parvizi et al. (2014) showed that fruit cracking was enhanced with an increase in mean relative humidity and a decrease in mean air temperature during the four-day period before each measurement of fruit cracking.

Environmental conditions have a significant influence on fruit quality (Schwartz et al., 2009). Pomegranate is a subtropical plant, and suboptimal climate conditions during fruit development can lead to physiological skin disorders, such as cracking. A study conducted in 2010 investigated the physical, chemical, and sensory characteristics of pomegranate fruits from the Glavaš cultivar grown at nine different locations in western Herzegovina. The study revealed that location, agricultural practices, and microclimate had some influence on the same cultivar (Gadže et al., 2012). Understanding the properties of fruit peels and how they are affected by different climatic conditions can help identify the best management practices needed in orchards and breeding programs. Previous research has shown that the Malas-e-Saveh pomegranate cultivar is sensitive to cracking, while the Yousefkhani cultivar is resistant (Saei et al., 2014). However, limited information is available regarding the impact of climatic conditions on the properties of pomegranate fruit peel. Therefore, this research was carried out to investigate the influence of climatic conditions on the physical and extensional properties of fruit peel in pomegranate cultivars Malas-e-Saveh (referred to as Malas in this paper) as a sensitive cultivar to cracking and Yousefkhani as a resistant cultivar to cracking, grown in three different climatic conditions in Iran.

MATERIALS AND METHODS

The study was conducted at Gorgan University of Agricultural Sciences and Natural Resources using a factorial arrangement in a completely randomized design with three replications.

Fruit material

To investigate the effect of climatic conditions on fruit peel, two pomegranate cultivars grown in three producing regions were examined. The producing regions included Saveh (1076 m above sea level, latitude 35.02 N, and longitude 50.19 E) in Markazi province, Sari (-13 m above sea level, latitude 36.40 N, and longitude 53.08 E) in Mazandaran province, and Aliabad Katool (63 m above sea level, latitude 36.58 N, and longitude 54.43 E) in Golestan provinces. Fruit samples were harvested at the stage of commercial maturity based on native growers' experience and immediately transported to the laboratory.

Physical analysis

Individual fruit weight was determined using a digital balance with an accuracy of 0.01 g. The length and diameter of the fruit crown were measured using digital calipers with an accuracy of 0.01 mm. Different parts of the fruits (Fig. 1A), including membranous septum (Fig. 1B), fleshy mesocarp (Fig. 1C), and the peel (with crown) (Fig. 1D) were manually separated from the arils (Fig. 1E) for further measurements. Peel and membranous septum thickness were measured at the equatorial zone of the fruits using digital calipers. Moisture percentage was determined by drying 10 g of the peel, fleshy mesocarp, and membranous septum in an oven at 70°C until a constant weight was reached.

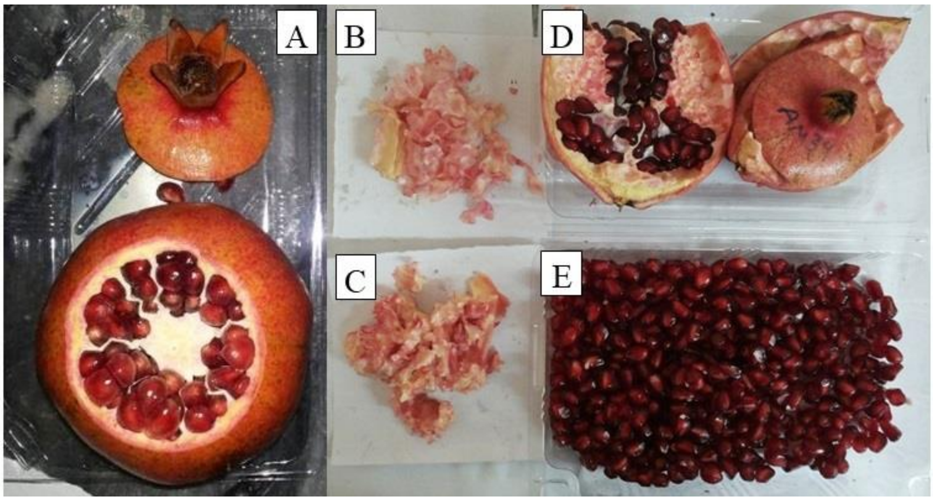

Fig. 1. Different parts of a pomegranate fruit in Malas cultivar (A), membranous septum (B), fleshy mesocarp (C), peel (with crown) (D), and arils (E).

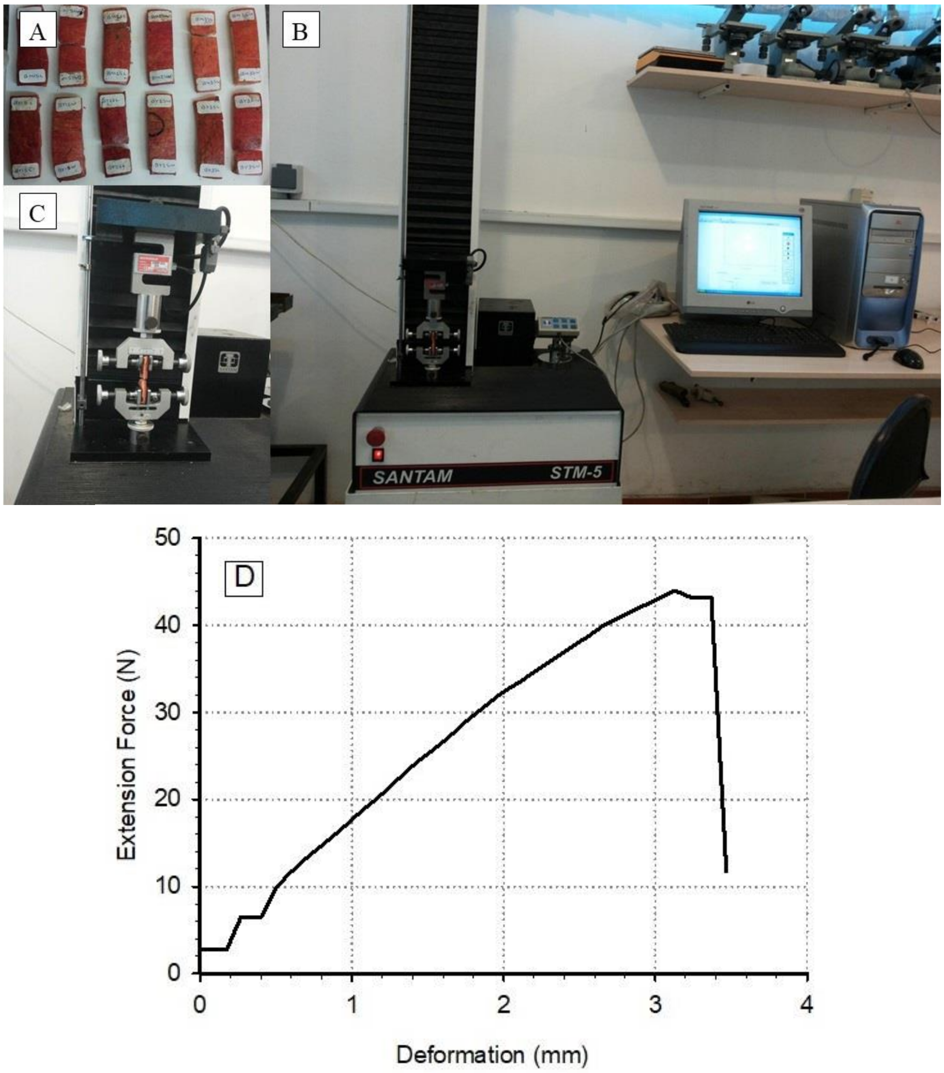

Fig. 2. Peel samples (A), Universal Testing Machine (STM-5, Santam Co.) (B and C), and force-deformation curve (D) of pomegranate fruits under extension test.

Extensional analysis

To determine the fruit's peel extension force and deformation, two peel samples (Fig. 2A) were prepared in the longitudinal and transversal directions from each fruit. The samples were taken from parts of the peel with uniform thickness but without any cracks and were rectangular, measuring 60 mm in length and 20 mm in width. An extension test was conducted using a Universal Testing Machine (Model: STM-5, Santam Co., Iran) (Fig. 2B and C) at a displacement rate of 30 mm/min. The extension force and deformations of the samples, as well as the force-deformation curve (Fig. 2D), were recorded in Excel software.

Statistical analysis

The data obtained from this study were analyzed statistically using JMP software, version 8. Numeric and percentage data were properly transformed before analysis, if necessary. The comparison of means was performed using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Physical properties

The analysis of variance results (Table 1) indicate that the interaction effect of cultivar and growth region was significant for crown length/diameter, peel percentage, peel thickness, and the number of septa at a 5% probability level. It was also significant for crown length and the percentage of fleshy mesocarp at a 0.1% probability level. However, the interaction effect was not significant for fruit weight, crown diameter, thickness and percentage of membranous septum, peel moisture percentage, fleshy mesocarp moisture percentage, and membranous septum moisture percentage. The main effect of cultivar was significant for crown diameter at a 1% probability level and for crown length, peels percentage and thickness, and the percentage of fleshy mesocarp at a 0.1% probability level. The main effect of growth region was significant for crown diameter at a 5% probability level, peel thickness at a 1% probability level, and for fruit weight, crown length/diameter, percentage of peel, number of membranous septa, thickness and percentage of membranous septum, percentage of fleshy mesocarp, and the percentage of peel moisture, fleshy mesocarp moisture, and membranous septum moisture at a 0.1% probability level.

Table 1. The analysis of variance of the effects of cultivar and growing region on some physical properties of pomegranate fruit.

Sources of variation	df	Mean of squares						
		Fruit weight	Crown length	Crown diameter	Crown L/D	Peel (%)	Peel thickness	Number of septa
Cultivar	1	0.044 ns	284.978 ***	64.078 **	0.078 ns	0.035 ***	7.006 ***	0.178 ns
Region	2	144455.6 ***	244.174 ***	33.010 *	0.693 ***	0.25 ***	4.211 **	7.511 ***
Cultivar × Region	2	8908.9 ns	44.907 ***	6.506 ns	0.236 *	0.00061 *	2.843 *	2.178 *
Error		5655.5	6.11	7.374	0.054	0.022	0.608	0.543
		Membranous septum (%)	Membranous septum thickness	Fleshy mesocarp (%)	Peel moisture	Fleshy mesocarp moisture	Membranous septum moisture	
Cultivar	1	0.371 ns	3.043 ns	35.01 ***	6.135 ns	32.873 ns	2.48 ns	
Region	2	4.357 ***	7.276 ***	31.539 ***	268.55 ***	91.916 ***	1581.8 ***	
Cultivar × Region	2	0.978 ns	3.634 ns	13.748 ***	2.583 ns	23.119 ns	108.718 ns	
Error		0.364	0.383	1.247	3.825	10.545	63.546	

***, **, *: Significant difference at 0.1%, 1% and 5% probability level, respectively. ns: no significant difference.

Table 2. The interaction effects of cultivar and growing region on some physical properties of pomegranate fruit.

Cultivars and regions	Crown length (mm)	Crown L/D	Peel (%)	Peel thickness (mm)	Number of septa	Fleshy mesocarp (%)
Malas - Sari	25.51c	1.51ab	28.37c	2.48d	7.33b	6.85d
Malas - Aliabad	22.22d	1.37bc	28.69c	2.86cd	6.67c	8.11c
Malas - Saveh	23.88cd	1.27c	32.19b	3.62ab	7.40b	8.96b
Yousefkhani - Sari	31.15a	1.66a	35.39a	3.75a	8.00a	9.21b
Yousefkhani - Aliabad	23.08d	1.23c	29.89bc	3.13bc	6.67c	7.85c
Yousefkhani - Saveh	28.06b	1.44b	36.11a	3.77a	7.00bc	10.60a
Cultivar × Region	P=0.001	P=0.015	P=0.034	P=0.012	P=0.022	P<0.001
Cultivar	P<0.001	P=0.232	P<0.001	P=0.001	P=0.569	P<0.001
Region	P<0.001	P<0.001	P<0.001	P=0.002	P<0.001	P<0.001

In each column, different letters indicate significant difference (at 1 or 5% probability level, LSD).

The Malas cultivar of Sari showed the highest crown length (31.15 mm), which was significantly different from Malas and Yousefkhani in other regions. On the other hand, the lowest crown length was observed in Malas of Aliabad and Saveh regions, as well as in Yousefkhani of Aliabad (Table 2). These results are consistent with previous studies that reported crown lengths ranging from 11.7 to 30.2 mm for various cultivars (Tehranifar et al., 2010a; Khadivi & Arab, 2021). The highest length-to-diameter ratio of the crown was observed in Malas and Yousefkhani of Sari (1.51 and 1.66, respectively), while both cultivars grown in Aliabad and Malas of Saveh showed the lowest ratio.

According to the results of this study, Yousefkhani of Sari and Saveh regions had the highest percentages of fruit peel (35.39% and 36.11%, respectively). In contrast, the lowest percentage of fruit peel was observed in the Malas of Sari and Aliabad regions, as well as in Yousefkhani of Aliabad (Table 2). Fischer et al. (2013) previously reported that the leathery peel and fleshy mesocarp accounted for 9-12% and 22-38% of the entire fruit weight, respectively. Previous studies have also reported that the percentage of aril is inversely related to the percentage of peel (Tehranifar et al., 2010a; Tehranifar et al., 2010b). Furthermore, Chandra et al. (2013) found a significant difference among pomegranate cultivars in the percentage of fruit peel (22.53% to 41.19%), which confirms the results of this study. However, the percentage of peel obtained in this study was slightly lower than the findings of other studies (Tehranifar et al., 2010b).

Peel thickness is an important criterion for selection, as fruits with thin peel are preferred for processing, while those with thick peel that resist transport and storage are chosen for fresh consumption (Mansour et al., 2015). However, consumers generally prefer pomegranate fruit with thin peel because it reduces fruit waste and is easier to peel (Radunić et al., 2015). The study found that Malas and Yousefkhani of Saveh and Yousefkhani of Sari had the highest peel thickness (3.62, 3.77, and 3.75 mm, respectively). In contrast, the lowest peel thickness was observed in the Malas of Sari and Aliabad regions (Table 2). The peel thickness in this study is consistent with the results of some other studies (Tehranifar et al., 2010b; Al-Aslan et al., 2023). Gadže et al. (2012) observed significant differences in the peel thickness of the Glavaš cultivar grown at nine locations in western Herzegovina. They found that Buna4 had the highest value (9.89 mm), while Stolac3 had the lowest value (5.91 mm). Saei et al. (2014) reported that Malas, the sensitive cultivar to fruit cracking, had a thinner peel than Yousef-Khani, the resistant one. However, there was no significant relationship between peel thickness and resistance to fruit cracking in pomegranate. According to their theory, the role of fruit peel in pomegranate cracking depends on its mechanical properties. This study found that the peel thickness of Yousefkhani of Aliabad was similar to Malas of Aliabad, confirming that pomegranate peel thickness depends on the cultivar and growth region. Singh et al. (2020) reported that varietal differences in cracking were attributed to peel structure and epidermal cell size.

The research findings revealed that Yousefkhani of Sari had a higher number of membranous septa compared to the other cultivars and regions. On the other hand, Malas and Yousefkhani of Aliabad, as well as Yousefkhani of Saveh, had the lowest number of membranous septa (Table 2). Schwartz et al. (2009) reported that the number of white membranous walls inside each fruit was 1.14-1.25 times higher in fruits obtained from Neweyaar compared to those from southern Arava. They suggested that the environmental conditions at Neweyaar promote a higher formation of these membranous walls, which in turn affects the number of arils and peel thickness. This higher formation of membranous walls was also reported to be the main reason for the higher juice content of fruits from this habitat (Schwartz et al., 2009). The study found that Yousefkhani of Saveh had the highest percentage of fruit fleshy mesocarp (10.6%), while Malas of Sari had the lowest percentage

(6.85%) (Table 2). According to Saei et al. (2014), the fleshy mesocarp of the peel contains parenchyma cells with air bubbles between them, resulting in less extensibility. It can be hypothesized that since the fleshy mesocarp is responsible for water absorption, this part may act as a stress source in the fruit.

Fruit weight is an important factor in pomegranate fruit production and marketing (Holland et al., 2009). The study found no significant difference in fruit weight between the cultivars, but there was a significant difference among the growth regions. The highest fruit weight was observed in the Saveh region (478.53 g), while the lowest fruit weight was observed in the Aliabad region (340.50 g) (Table 3). These results are consistent with other studies that have reported fruit weights ranging from 133.8 to 509.82 g (Fawole & Opara, 2014). Schwartz et al. (2009) reported that in 2006, fruit weight was higher in fruits produced in the southern Arava (desert climate) compared to those from Neweyaar (Mediterranean temperate to subtropical climate). However, in 2007, the fruits obtained from Neweyaar were heavier than those harvested from the southern Arava. These findings align with the results of the present study, where fruits from the Saveh region, with a desert climate, had higher weight compared to the Aliabad and Sari regions with humid climates. Differences in fruit weight among various pomegranate cultivars have been attributed to ecological and genetic variations (Joshi et al., 2021). An increase in fruit size can be attributed to an increase in aril size and juice content as fruits reach maturity (Lyu et al., 2020).

The results of this study indicated that Yousefkhani had a significantly higher crown diameter compared to Malas (Table 3). Additionally, the Saveh region exhibited a higher fruit crown diameter (19.65 mm) compared to the other two regions. Previous studies have reported slightly lower (Nikdel et al., 2016), or a wider range of crown diameters (17.1 to 26.9 mm) (Radunić et al., 2015).

Table 3. The effects of cultivar and growing region on some physical properties of pomegranate fruit.

	Fruit weight (g)	Crown diameter (mm)	Membranous septum (%)	Membranous septum thickness (mm)	Peel moisture (%)	Fleshy mesocarp moisture (%)	Membranous septum moisture (%)
Cultivars							
Malas	417.29	17.61b	1.78	0.39	60.85	73.08	57.29
Yousefkhani	417.24	19.30a	1.91	0.35	61.37	74.29	57.63
Regions							
Sari	435.77b	18.02b	1.91b	0.32b	63.40a	75.52a	62.92a
Aliabad	340.50c	17.69b	1.43c	0.31b	62.21b	72.03b	49.22b
Saveh	475.53a	19.65a	2.18a	0.47a	57.73c	73.50b	60.24a
Cultivar × Region	P=0.213	P=0.418	P=0.074	P=0.973	P=0.512	P=0.118	P=0.187
Cultivar	P=0.998	P=0.004	P=0.316	P=0.213	P=0.209	P=0.081	P=0.844
Region	P<0.001	P=0.014	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001

In each column, different letters indicate significant difference (at 1 or 5% probability level, LSD).

Table 4. The analysis of variance of the effects of cultivar, growing region and sampling direction on pomegranate fruit peel deformation and peel extension force.

Sources of variation	df	Mean of squares	
		peel deformation	peel extension force
Cultivar	1	5.08 *	2370.704 ***
Region	2	30.913 ***	150.396 ns
Sampling direction	1	1.478 ns	158.292 ns
Cultivar × Region	2	0.427 ns	52.164 ns
Cultivar × sampling direction	1	0.311 ns	21.78 ns
Region × sampling direction	2	3.296 *	246.766 ns
Cultivar × Region × sampling direction	2	3.325 *	88.136 ns
Error	96	1.066	146.963

*** and *: Significant difference at 0.1% and 5% probability level, respectively. ns: no significant difference.

Membranous septa are papery tissues that compartmentalize groups of arils without attaching to them (da Silva et al., 2013). The results of this study showed no significant difference between the two cultivars in terms of the percentage and thickness of membranous septum (Table 3). However, there were significant differences in the percentage of membranous septum between the Saveh (2.18%) and Aliabad (1.43%) regions, with both regions differing significantly from Sari. Similarly, Saveh had the highest thickness of membranous septum (0.47 mm) among the growing regions. According to Kianmehr et al. (2011), 41.5% of pomegranate weight in the Alak cultivar consisted of epicarp and mesocarp. The present study found no significant difference in the percentages of moisture in the peel, fleshy mesocarp, and membranous septum between the two cultivars (Table 3). The results showed that Sari had the highest percentage of peel moisture (63.40%), while Saveh had the lowest (57.73%), with both regions differing significantly from Aliabad. The percentages of peel moisture found in Malas and Yousefkhani were slightly higher than those found in five Iranian pomegranate cultivars in South Khorasan Province (Nikdel et al., 2016). The highest percentage of fleshy mesocarp moisture was observed in Sari (75.52%), which was significantly different from the other regions. Additionally, the highest percentage of membranous septum moisture was observed in Sari and Saveh regions (62.92% and 60.24%, respectively). These results align with the findings of Kianmehr et al. (2011), who reported that the moisture content of pomegranate epicarp and mesocarp was 51.71% and 73.03%, respectively.

Extensional properties

The results of the analysis of variance (Table 4) showed that the triple interaction effect of cultivar, growth region, and sampling direction was significant at a 5% probability level for peel deformation, but not for peel extension force. The interaction effects of cultivar and sampling direction, cultivar and growth region, and growth region and sampling direction, as well as the main effects of growth region and sampling direction on peel extension force, were not significant. However, the main effect of cultivar on peel extension force was significant at a 0.1% probability level.

According to the findings of the current study, the highest peel deformation was observed in the transversal direction in Malas of Saveh (6.489 mm), while the lowest deformation was observed in the transversal direction in Malas and Yousefkhani of Sari, as well as in the longitudinal direction in Yousefkhani of Sari and in Malas and Yousefkhani of Aliabad (Fig. 3). Previous research by Sadrnia et al. (2009) found that Crimson Sweet watermelon had the highest failure deformation under load in the transversal direction, while Charleston Gray had the lowest failure deformation in the longitudinal direction for medium-sized fruits. They also noted that changes in the peel white layer affected the mechanical properties of these watermelon cultivars. Additionally, watermelon peel strength was higher in the transversal direction compared to the longitudinal direction. Environmental conditions such as temperature and relative humidity have a plasticizing effect on the mechanical properties of cuticles by reducing cuticle stiffness and strength (Dominguez et al., 2011).

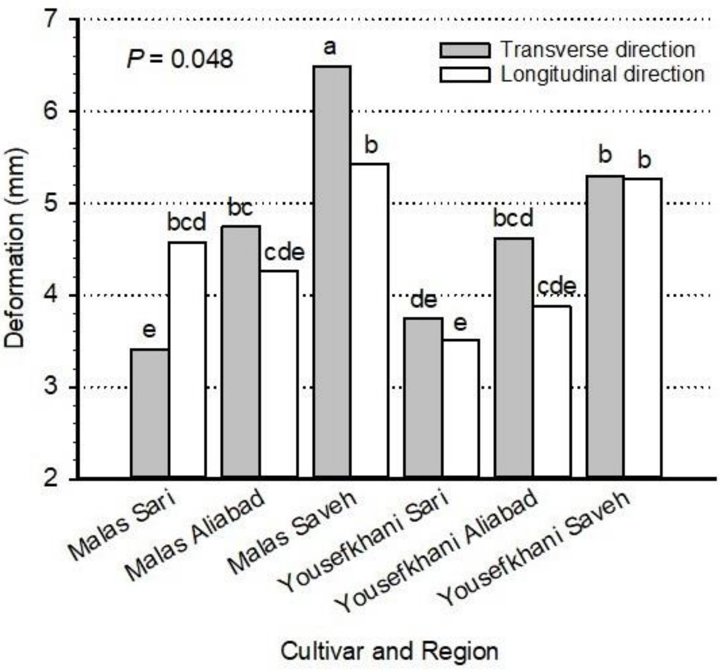

Fig. 3. The interaction effects of cultivar, growing region and sampling direction on pomegranate fruit peel deformation.

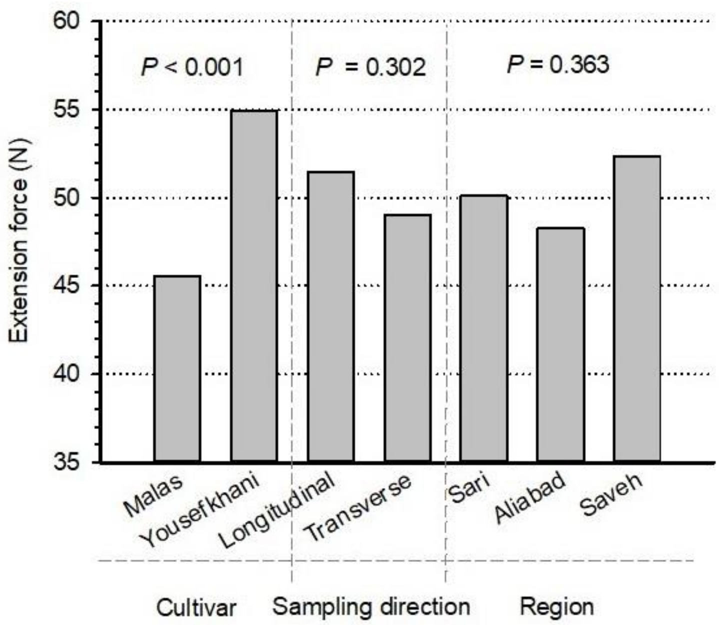

Fig. 4. The effects of cultivar, growing region and sampling direction on pomegranate fruit peel extension force.

The results of this study showed that the peel extension force varied significantly among the studied cultivars, with Yousefkhani (54.93 N) having a higher extension force than Malas (45.56 N) (Fig. 4). However, the differences among the sampling directions and growing regions were not significant. The fruit skin has a dual role as it protects the fruit from environmental stresses while also playing a critical role in resisting internal growth pressures, controlling fruit expansion, and maintaining fruit integrity (Joshi et al., 2021). Understanding the mechanical properties of pomegranate fruit peel is important for improving harvesting, transport, and postharvest handling of pomegranate fruits (Fawole & Opara, 2014). Some pomegranate cultivars have relatively thinner and softer fruit peels, making them more susceptible to physical damage such as cracking and splitting (Holland et al., 2009).

According to Saeidirad et al. (2015), harvesting time affects the extension force of pomegranate fruit peel. The extension force of the fruit peel increased during prolonged harvesting periods, with a significant difference observed between the peel extension force in fruits harvested in late October and those harvested in mid-November. This increase in extension force can be attributed to fruit growth completion and a decrease in peel moisture content. The Shishe-Kab cultivar had the lowest extension force compared to Ardestani and Malas, despite having a thicker peel. The highest extension force was observed in Ardestani, indicating that an increase in peel thickness does not necessarily raise the peel extension force. These findings align with the present study, which found that peel extension force was consistent across different regions even when peel thickness varied. In other words, there is no direct relationship between peel thickness and extension force. Saei et al. (2014) reported that the correlation between peel thickness and resistance to fruit cracking in pomegranate was not significant. They also illustrated that the role of fruit peel in pomegranate fruit cracking depends on its mechanical properties. These results are consistent with the observations of this study, which found similar peel thickness in Aliabad for both Yousefkhani (resistant to cracking) and Malas (sensitive to cracking) cultivars. Therefore, it can be concluded that peel thickness depends on the cultivar and growing region, while resistance to cracking depends on the mechanical properties of the fruit peel.

CONCLUSION

Pomegranates are naturally adaptable to various climatic conditions, and they are cultivated in different regions worldwide. However, different climatic conditions can impact the quality of pomegranate fruit. According to the findings of this study, most pomegranate fruit characteristics were significantly influenced by cultivar and growing region. Yousefkhani, as a resistant cultivar to cracking, exhibited a thicker peel and a higher percentage of fleshy mesocarp compared to the sensitive cultivar, Malas. Yousefkhani, with its higher tolerance to extension force, is suitable for storage and transportation and may have a higher tolerance to cracking. Furthermore, this research indicated that fruits produced in arid and desert regions of Saveh had a higher weight. Given the increasing desire to grow pomegranates worldwide, it is crucial to consider the influence of climatic conditions on the qualitative properties of pomegranate fruit, particularly when introducing new superior cultivars to different planting regions. Further studies are necessary to explore the effects of climatic conditions on the qualitative characteristics of pomegranate flowers, fruit, and peel in other cultivars and regions.

Conflict of interest

The authors have no conflict of interest to report.

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