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Research Article

Correlation between Sweet Cherry Quality Attributes and Fruit Cracking Index

Mihai Chivu[1,2], Mădălina Butac[1], Oana Hera[1]* and Adrian Asănică[2]

[1]Research Institute for Fruit Growing Pitesti-Mărăcineni, 402 Mărului, Mărăcineni, 117450, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

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***Corresponding author:** Oana Hera, Research Institute for Fruit Growing Pitesti-Mărăcineni, 402 Mărului, Mărăcineni, 117450, Romania,
E-mail: oana.hera@yahoo.com

ORCiD: https://orcid.org/0009-0006-1210-1863

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Abstract

Sweet cherry skin cracking, particularly due to rainfall, presents a significant challenge for commercial production. This issue impacts fruit quality and marketability, making it crucial to identify effective, accessible solutions tailored to local climatic conditions. Understanding the relationship between fruit quality parameters and cracking susceptibility is essential for supporting farmers and improving production practices. However, in an attempt to obtain higher quality fruit, it is possible that sometimes, especially if there is significant rainfall during the fruit ripening period, producers neglect the possibility that the fruit is much more susceptible to cracking. A two-year experience (2022-2023) investigated how certain quality parameters—such as fruit weight, firmness, pH, total soluble solids (TSS), fruit maturity index, and color—affect the cracking of sweet cherries. The research focused on three cherry cultivars ('Ferrovia', 'Kordia', and 'Skeena') grafted onto the 'IP-C8' rootstock. By examining these parameters, the study sought to identify factors that contribute to cracking and offer insights for improving fruit quality.

The 'Kordia' cv. had the highest induced cracking index (1.67), followed by the 'Skeena' cv. at 1.27, and 'Ferrovia' cv. with a lower value of 0.27. Higher values indicate that 'Kordia' and 'Skeena' are more susceptible to cracking under stress conditions compared to 'Ferrovia'. The induced cracking index highlights how cultivars respond to stress conditions, such as heavy rainfall. The 'Kordia"s higher value suggests it is more vulnerable to cracking under stress compared to 'Ferrovia' cv., which might be more resilient.

Introduction

Cherries, native to Europe and western Asia, have become a globally cultivated fruit, valued for their nutritional benefits and versatile use in various food products. This essay argues that sweet cherries (Prunus avium), despite their demanding cultivation and supply chain requirements, hold significant importance in global agriculture due to their economic value and health benefits [1].

Firstly, cherries belong to the Rosaceae family and the genus Prunus, with the primary commercial species being sweet cherries (Prunus avium) and tart cherries (Prunus cerasus). While ground cherries (Prunus fruticosa Pall.) also exist, they are less significant in global trade. Among these, sweet and tart cherries are the most important for international markets, with sweet cherries being particularly prized for their flavor and nutritional profile.

The cultivation of sweet cherries presents several challenges, making it a more complex and costly endeavor compared to tart cherries. The need for meticulous care throughout the supply chain—from orchard management to post-harvest handling—ensures that the fruit maintains its premium quality for the fresh market. This high level of care involves controlling environmental conditions, preventing diseases and pests, and employing precise harvesting techniques to avoid damage to the delicate fruit [2]. As a result, the production costs for sweet cherries are significantly higher, reflecting their premium status in the market. Despite these challenges, the economic

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and health benefits of sweet cherries justify the investment. Sweet cherries are a rich source of vitamins, minerals, and antioxidants, making them a valuable addition to a healthy diet. Their high polyphenol content, particularly anthocyanins, provides powerful antioxidant properties [3] that help reduce inflammation and lower the risk of chronic diseases such as heart disease, diabetes, and cancer. The presence of vitamins C and A, potassium, and fiber further enhances their nutritional value, supporting immune function, skin health, heart health, and digestive health [4]. The global demand for sweet cherries continues to grow, driven by increasing consumer awareness of their health benefits and the desire for fresh, high-quality fruit. This demand fuels the need for advanced agricultural practices and innovative supply chain solutions to meet market expectations. By investing in improved cultivation techniques, storage, and transportation methods, producers can ensure the consistent availability of premium sweet cherries, thereby supporting both economic growth and public health. A recent analysis of public health data reveals an alarming increase in the prevalence of cardiovascular diseases, cancer, lipid metabolism disorders, allergic conditions, and various nervous system diseases [5]. Understanding the causes of cherry cracking [6] and implementing targeted management practices can mitigate this issue, thereby enhancing the sustainability and profitability of cherry production [7]. Cherry cracking can affect up to 90% of the crop in severe cases, primarily resulting from direct water uptake through the fruit skin [8]. However, several other factors, such as the variety of cherry grown, the properties of the fruit skin, and climatic conditions, also play a role in the occurrence and severity of cracking [9]. Recognizing the different forms of cracking—stem end cuticular fractures, nose or apical cracking, and side cracking—is crucial for developing effective prevention strategies [10]. Cherry cracking is a significant issue in cherry production, particularly in regions with varying climatic conditions. The problem primarily arises due to fluctuations in soil moisture and rapid changes in weather, leading to increased fruit cracking. Recent research has focused on understanding the physiological mechanisms behind cracking and developing management strategies to mitigate this issue. Rombolà, et al. [11] explored how irrigation practices influence cherry cracking. Their study highlights that maintaining consistent soil moisture levels is crucial for reducing the incidence of fruit cracking. They found that deficit irrigation strategies when not properly managed, could exacerbate cracking due to stress-induced changes in fruit physiology. Chen, et al. [12] investigated the impact of weather conditions, particularly rainfall and humidity, on cherry cracking. Their research shows that sudden rain events following dry periods can significantly increase cracking. The study suggests using weather forecasting to anticipate and mitigate the effects of unexpected rainfall.

The objective of this research is to determine how various quality attributes of sweet cherries correlate with their susceptibility to cracking. By evaluating cherries grown in a controlled environment, this study seeks to identify key attributes that may influence cracking and provide insights into how to enhance fruit quality while minimizing the risk of damage.

Materials and methods

Understanding the quality of sweet cherries is crucial for assessing their market value and susceptibility to issues such as fruit cracking. In this study, several key fruit quality parameters are measured to provide a comprehensive evaluation of cherry quality.

This study involves the analysis of fruit quality parameters for three sweet cherry cultivars ('Kordia', 'Ferrovia' and 'Skeena') harvested in an open field trial in randomized block design with three repetitions plots (8 plants/ genotype/ repetition) between 2022-2023, at the Research Institute for Fruit Growing Pitești-Mărăcineni (RIFG), in South of Romania at 44°54'12" Northern latitude, and 24°52'18" Eastern longitude, 284 m altitude.

The average fruit weight was determined by weighing a sample of 50 fruits from each repetition at each harvest using a scale (in grams), after the harvesting work depending on the ripening period of each genotype, then a weighted average weight was calculated. The pH values of sweet cherry fresh juice were measured using a specialized pH meter ((ISFET pH Meter, IQ 125, Japan).

The total soluble solids content was measured using a digital refractometer Haana Instruments 96801 and values were recorded in °Brix. The fruit firmness was assessed non-destructively using a Bareiss HPE II Fff penetrometer for each sample.

The cracking index (CI) was determined in the first sub-batch of cherries according to the method of [13] and modified by Christensen, 1972 [14]. For this, the 150 cherries were divided into three replicates of 50 fruits and immersed in 2 L containers filled with distilled water (20 ± 1 ◦C). After 2, 4, and 6 h, the fruits were observed for macroscopic cracks. At each time, cracked cherries were removed and counted, and fruits without cracks were re-incubated. The CI was calculated as follows: CI = ((5a + 3b + c) * 100)/150 (1) where a, b, and c represent the number of cracked cherries after 2, 4, and 6 h of immersion, respectively.

The skin color of sweet cherry fruit is an essential quality attribute that influences both its aesthetic appeal and marketability [15]. This study focuses on the precise measurement of cherry skin color using a colorimeter based on the Huntel L*, a*, b* color system. This methodology provides a detailed understanding of the fruit's hue, brightness, and chromaticity [16].

The analyses were conducted three times, and the data were presented as mean ± standard deviation (SD). Excel 2021 (XLSTAT) was utilized for statistical analysis of the data. One-way analysis of variance (ANOVA), two-way ANOVA, and Duncan's multiple range tests were carried out. Correlations were performed using SPSS13.0.

Results and discussions

Biometric characteristics of sweet cherry fruit

The biometric characteristics of sweet cherry fruit, such

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as size and texture, are important for assessing fruit quality and marketability. These characteristics are expressed through parameters such as average weight and firmness [5]. Significant variability has been observed between different cherry genotypes regarding these indicators, reflecting the influence of both genetic and environmental factors. Both 'Ferrovia' cv. and 'Kordia' cv. had higher average fruit weights (7 g/fruit) compared to 'Skeena' cv. (6.65 g/fruit). This may indicate that heavier fruits, such as those from 'Ferrovia' and 'Kordia', could be more prone to cracking due to increased water uptake during rainfall. The cultivars 'Skeena' (47.78 N) and 'Ferrovia' (49.30 N) showed relatively high firmness values (Table 1). Firmer fruits generally have a more robust skin, which might help reduce the susceptibility to cracking, though this is not always a guarantee. Lower fruit pH is associated with higher fruit acidity, which can affect the firmness of the cherry skin [17] Fruit with higher acidity often has a weaker skin structure, which can make it more susceptible to physical stress and cracking. The pH value of sweet cherry juice is a critical quality attribute that affects flavor, shelf life, and overall fruit quality. Accurate pH measurement is essential for assessing the acidity of the juice, which can influence its taste and stability 'Skeena' cv. (3.55) exhibited a slightly lower pH compared to 'Ferrovia' cv. and 'Kordia' cv., indicating higher acidity. Increased acidity may correlate with a higher risk of cracking, as lower pH levels can affect fruit skin integrity. 'Kordia' cv. had a higher TSS (21,27°Brix) compared to 'Skeena' cv. (17.81°Brix), which may suggest that higher sugar content could be associated with reduced cracking. However, excessive sugar might also affect the fruit's structural integrity, influencing susceptibility.

Fruit color is a key quality attribute that influences marketability and consumer preference. In our study of sweet cherry cultivars—'Ferrovia', ‚Kordia', and ‚Skeena'—color measurements were taken to assess potential correlations with fruit cracking susceptibility. Both ‚Skeena' cv. and ‚Ferrovia' cv. had the same L* value (24,98), indicating similar brightness levels (Table 2). Higher L* values generally correspond to brighter fruit colors, which could influence market appeal.

The 'Kordia' cv. had a significantly lower a* value compared to 'Skeena' cv. and 'Ferrovia' cv., which had higher a* values (15.74). Higher a* values indicate a stronger red coloration.

The cultivars with more intense red hues might be more attractive to consumers but could also have different cracking susceptibility based on skin texture and structural integrity. 'Kordia' cv. had a lower b* value (1.43), indicating a less yellowish hue compared to 'Ferrovia' cv. (4.09). Higher b* values suggest more yellow tones in the fruit color. The relationship between b* values and cracking susceptibility is less straightforward but may interact with other color parameters and skin characteristics.

The natural cracking index measures the inherent tendency of cherries to crack under normal conditions without additional stress. 'Kordia' cv. exhibited the highest natural cracking index (0.30), indicating a greater susceptibility to cracking compared to 'Ferrovia', which had a lower index of 0.10. This suggests that 'Kordia' cv. may be more prone to cracking under typical growing conditions, possibly due to its skin characteristics or structural properties. The induced cracking index evaluates the fruit's susceptibility to cracking when subjected to additional stress, such as high moisture conditions. The 'Kordia' cv. had the highest induced cracking index (1.67), followed by the 'Skeena' cv. at 1.27, and 'Ferrovia' cv. with a lower value of 0.27 (Table 3).

Higher values indicate that 'Kordia' and 'Skeena' are more susceptible to cracking under stress conditions compared to 'Ferrovia'. This greater susceptibility could be due to factors such as skin elasticity, water uptake, and internal fruit structure.

To improve the quality and reduce cracking in sweet cherry production, understanding how various fruit attributes correlate with cracking susceptibility is essential. In this analysis, it is examined the relationships between fruit weight, firmness, pH, color attributes (L*, a*, b*), and both natural and induced cracking indices in three sweet cherry cultivars: 'Ferrovia', 'Kordia', and 'Skeena'.

Correlation with quality parameters

Fruit weight and cracking indices natural cracking index: Higher fruit weight might suggest a larger fruit size, which can potentially increase the risk of cracking if the fruit is more susceptible to water uptake. If 'Ferrovia' cv. and 'Kordia' cv. have larger fruit weights compared to 'Skeena' cv., they might exhibit a higher natural cracking index if their skins cannot support the added volume. Induced cracking index: Similarly,

Table 1: Biometric and biochemical characteristics of sweet cherry fruit.

Cultivar*	Berry weight (g)	Firmness (N)	pH	TSS (°Brix)
Ferrovia	7.20 ± 0.4^{a}	49.30 ± 7.91^{a}	3.63 ± 0.14^{a}	19.51 ± 2.06^{b}
Kordia	7.17 ± 1.05^{a}	35.87 ± 6.83^{b}	3.63 ± 0.12^{a}	21.27 ± 2.25^{a}
Skeena	6.65 ± 0.39^{b}	47.78 ± 3.89^{a}	3.55 ± 0.13^{b}	17.81 ± 1.01^{c}

Note: *Different letters between cultivars denote significant differences (Duncan test. $p < 0.05$).
Different letters between susceptible and resistant cultivars denote significant differences (LSD test. $p < 0.05$)

Table 2: Colorimetric characteristics of sweet cherry fruit.

Cultivar *	L*	a*	b*
Ferrovia	24.98 ± 1.68^{a}	15.74 ± 3.88^{a}	4.09 ± 1.59^{a}
Kordia	23.04 ± 1.01^{b}	7.70 ± 3.31^{b}	1.43 ± 0.84^{c}
Skeena	24.98 ± 1.24^{a8}	15.21 ± 3.47^{a}	3.59 ± 1.24^{b}

Note: *Different letters between cultivars denote significant differences (Duncan test. $p < 0.05$).
Different letters between susceptible and resistant cultivars denote significant differences (LSD test. $p < 0.05$)

Table 3: Natural and induced index of sweet cherry fruit.

Cultivar	Natural cracking index	Induced cracking index
Ferrovia	0.10 ± 0.10^{c}	1.33 ± 1.13^{b}
Kordia	0.30 ± 0.15^{a}	1.67 ± 0.63^{a}
Skeena	0.18 ± 0.2^{b}	1.27 ± 0.94^{b}

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larger fruits with higher weights might be more prone to cracking under stress conditions if the fruit skin cannot handle increased water absorption. Thus, 'Kordia' cv. with a higher induced cracking index might also have a larger fruit weight compared to 'Ferrovia' cv. and 'Skeena' cv.

Firmness and cracking indices

Natural cracking index: Fruit firmness is often associated with the structural integrity of the fruit skin. Higher firmness typically indicates a more robust skin, which may reduce the likelihood of natural cracking. The cultivar 'Skeena' with higher firmness might exhibit lower natural cracking indices.

Induced cracking index: Firmness may also impact how the fruit responds to stress. A firmer fruit could potentially withstand higher moisture levels better, thus reducing the induced cracking index. Thus, if 'Skeena' cv. has higher firmness, it might also show a lower induced cracking index compared to softer like 'Ferrovia'cv.

pH and cracking indices: Natural cracking index: pH affects the fruit's acidity, which in turn impacts the skin's texture and strength. Lower pH (higher acidity) might lead to weaker fruit skins, which could increase natural cracking. Therefore, if 'Skeena' cv. has a lower pH, it might be more prone to cracking compared to cultivars like 'Ferrovia' with higher pH values.

Induced cracking index: Increased acidity (lower pH) might also contribute to higher susceptibility to cracking under stress conditions. Higher acidity could weaken the fruit skin's ability to withstand rapid water uptake, increasing the induced cracking index. Thus, 'Skeena' cv. with lower pH might have a higher induced cracking index.

Color attributes (L, a, b*) and cracking indices

L* (Brightness)

Natural cracking index: Higher brightness (higher L*) might correlate with thicker or more resilient fruit skins, potentially reducing natural cracking. Therefore, brighter cultivars like 'Skeena' and 'Ferrovia' might show lower natural cracking indices.

Induced cracking index: The correlation with induced cracking is less direct but could suggest that brighter fruits may be less prone to severe cracking under stress.

a* (Red-Green Chromaticity)

Natural cracking index: Higher a* values (more red coloration) might be associated with better fruit ripeness and skin quality, potentially reducing natural cracking. Therefore, varieties with higher a* values like 'Skeena' cv. and 'Ferrovia' cv. might have lower natural cracking indices.

Induced cracking index: Intense red coloration could suggest a stronger skin structure, which might mitigate cracking under stress conditions.

b* (Blue-yellow chromaticity)

Natural cracking index: Lower b* values (less yellow) might be associated with less robust fruit skins, potentially increasing natural cracking. Therefore, 'Kordia cv. ' with a lower b* might have a higher natural cracking index.

Induced cracking index: The correlation is more complex but could indicate that less yellow fruit skins (lower b*) might be more prone to cracking under stress.

Conclusion

The correlation between fruit attributes and cracking indices provides valuable insights for cherry production. Higher fruit weight and lower firmness are generally associated with increased susceptibility to cracking. Lower pH levels and certain color attributes might also influence cracking susceptibility. Understanding these relationships helps in selecting and managing cherry varieties to enhance fruit quality and reduce cracking. By focusing on these parameters, growers can better address the challenges of fruit cracking and improve overall production efficiency.

Correlation with quality parameters

Natural cracking index: The natural cracking index reflects the fruit's baseline susceptibility to cracking. The cultivars with higher natural cracking indices, such as 'Kordia', may need more careful management to minimize cracking during the growing season. Induced Cracking Index: The induced cracking index highlights how cultivars respond to stress conditions, such as heavy rainfall. The 'Kordia''s higher value suggests it is more vulnerable to cracking under stress compared to 'Ferrovia' cv., which might be more resilient.

The analysis of natural and induced cracking indices reveals important differences among the sweet cherry cultivars. 'Kordia' showed higher values for both indices, indicating a greater overall susceptibility to cracking under both normal and stressed conditions. 'Ferrovia' had lower values, suggesting better resistance to cracking. Understanding these indices helps in selecting suitable varieties and implementing effective management practices to mitigate cracking and improve fruit quality.

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