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THE RELATIONSHIP BETWEEN THE PHYSICAL ATTRIBUTES OF CHERRIES AND THEIR QUALITY TRAITS

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Abstract

The research question seeks to examine the extent to which the physical attributes and subsequent impact on quality traits of cherries may influence the sustainable choices made by both merchants and consumers. Seven varieties were selected to that purpose and measured for the retained investigated features. Two physical characteristics, diameter and height, and two quality traits, firmness and soluble substance were paired and studied for eventual correlation. The correlation coefficients are relevant for a limited number of varieties, almost half of the analysed ones, and they indicate an acceptable to moderate correlation between the screened features. A larger diameter or height does not necessarily mean a larger amount of sugar or soluble substance, as demonstrated by the absence of correlation for the richest analysed variety. Subsequently the diameter cannot be used as a quality indication and cannot support a sustainable choice. The physical appearance of the cherries cannot represent an element that supports the sustainable choice of merchants or consumers when the quality of cherries is a relevant reference.

***Key words**: sustainable choice, cherries, firmness, soluble substances, diameter, height, correlation.*

INTRODUCTION

The growth of cherries is significant in the global agricultural industry, with notable focus on the fruit's quality and physical characteristics (Shahbazi et al., 2013). Grasping the link between physical properties and quality indicators of cherries is indispensable for improving production efficacy and fulfilling consumer expectations (Romano et al., 2006; Shewfelt, 2006). Investigation in this domain is pivotal to identify principal traits influencing cherries' overall quality, including parameters such as diameter, height, and firmness.

Through the examination of these variables, scholars can obtain crucial understanding regarding factors impacting the sensory perception and market valuation of cherries (Asănica et al., 2015).

Additionally, an exhaustive analysis of these connections can result in the formulation of methodologies to enhance cherry production workflows and ascertain uniform quality benchmarks (Pal et al., 2017).

Within this framework, examining the relationship between cherry physical characteristics and quality attributes holds considerable relevance for the agricultural domain and consumer contentment (Devasirvatham et al., 2022; Dudu et al., 2015). The exploration concerning the association amid cherry physical traits and quality metrics is grounded in the necessity to elevate the comprehension of elements swaying cherry quality determinants. As evidenced in the physical properties of cherries, comprising diameter, height, and firmness, significantly influence their general quality (Asănică et al., 2011). Investigating the distinctions discerned in these attributes across diverse cherry cultivars allows investigators to reveal vital discernments into elements inducing variations in fruit quality (Faniadis et al., 2010; Romano et al., 2006). Furthermore, scrutinizing the interactions between these physical traits and quality metrics such as taste, shelf longevity, and market worth is pivotal for formulating strategies to refine cherry production and satisfy consumer preferences (Paunovic et al., 2022). This research endeavours to augment the extant knowledge reservoir by elucidating the complex associations between cherry physical traits and quality metrics, ultimately guiding industry methodologies towards improving cherry quality and consumer contentment.

Comprehending the relationship between physical attributes and quality aspects of cherries manifests a noteworthy research quandary in agricultural science. Examination of variables such as diameter, stature, and firmness, along with their influence on the aggregate quality of cherries, holds importance for refining production techniques and catering to consumer expectations (Romano et al., 2006; Ricardo-Rodrigues et al., 2023). Prior inquiries have accentuated the relevance of said physical properties in ascertaining the commercial worth and sensory characteristics of cherries. Nonetheless, a lacuna exists in scholarly literature concerning the precise correlations among these attributes and quality benchmarks. Via an in-depth analysis of statistical data and experimental outcomes, the present study aspires to tackle this research quandary holistically (Esti et al., 2002; Chockchaisawasdee et al., 2016; Devasirvatham et al., 2022). By methodically scrutinizing the facts, this investigation seeks to elucidate the convoluted interrelations between cherry physical attributes and quality dimensions, proffering indispensable insights for both industry specialists and academicians.

Investigation into the association of cherry physical attributes with quality traits possesses notable implications for agricultural and consumer domains (Muskovics et al., 2016). By clarifying the linkages involving traits such as diameter, height, and firmness with quality markers, this research augments comprehension of cherry growth and development, also yielding pertinent insights for producers and consumers. The conclusions lay groundwork for precise agricultural approaches, aiding enhanced cultivation tactics which might elevate total crop yields and quality (Mateos-Fierro, 2020). Moreover, the identified associations could steer consumer choices, shaping marketing tactics and assuring buyer contentment. Additionally, the statistical examinations performed on the dataset highlight the robustness of the observed linkages, affirming the reliability and validity of the study's outcomes. These insights are critical for advancing cherry cultivation techniques and fine-tuning product quality, thus contributing meaningfully to the broader agricultural sector (Kappel et al., 2012; Tzouramani et al., 2014). Subsequent investigations may expand upon these findings to propel forward innovation and sustainability within the cherry sector, fostering economic enhancement and addressing consumer needs effectively (Janes et al., 2010; Holusova et al., 2023; Demirsoy, 2004; Kappel et al., 1996).

Consumer Preferences. Paunović et al. (2022) and Asănică et al. (2018) conducted a survey to evaluate consumer attitudes on the most important characteristics of cherry fruit, and found that “the attitude toward fruit firmness, fruit size, and presence of a stalk and the stalk length” depended on respondents’ residence and sex, and that “the attitude toward fruit firmness, fruit size, and presence of a stalk” were influenced by the age of the respondents (Paunović et al., 2022; Asănică et al., 2018).

The perception of fruit firmness varied considerably by place of residence and gender of respondents. Urban and rural consumers may favour firmness differently, perhaps due to differences in storage conditions or cultural preferences. Additionally, men and women may have distinct preferences, potentially influenced by factors such as taste or use in cooking compared to direct consumption (Thornsbury et al., 2012).

Older and younger consumers showed different attitudes towards firmness. Older respondents might prefer firmer cherries due to better texture retention during storage, while younger consumers might focus on the immediate consumption experience.

Like firmness, preferences for cherry size were influenced by the location and gender of respondents. This could be related to factors such as the typical use of cherries in local cuisines or aesthetic preferences that vary between genders.

Age also played a role in determining the preferred size of the fruit. Younger consumers may prefer larger cherries because they are often perceived as juicier and more satisfying, while older consumers may favour other factors over size.

The presence of a strain and its duration also depend on the demographic factors of the respondents. These attributes can be important for a variety of reasons, such as the convenience of food or the aesthetic appeal of fruit (Ross et al., 2009; Bujdosó et al., 2020).

It is interesting to note that although the presence of a strain influenced consumer attitudes in different age groups, the length of the strain did not show significant variation with age. This suggests that while the presence of the stem is a universal factor considered, its length may be more subjective.

Understanding these nuanced consumer preferences can help cherry growers and retailers tailor their products to better meet the demands of their target market segments (Calvo-Porral et al., 2018; Revell, 2008).

Marketing campaigns can be designed to highlight specific attributes preferred by certain demographics. For example, promoting the firmness and size of cherries in urban areas or to younger consumers (Correia et al., 2017).

Retailers can segment their products based on these preferences, offering different varieties or styles of packaging that cater to the distinct tastes of different consumer groups.

Growers can focus on selecting and growing cherry varieties that meet the specific preferences highlighted by the study, such as ensuring optimal firmness and desired size for the most demanding consumer segments.

By aligning product offerings with consumer preferences, stakeholders in the cherry industry can increase customer satisfaction and increase sales (Correia et al., 2017).

MATERIALS AND METHODS

The research question seeks to examine the extent to which the physical attributes and subsequent impact on quality traits of cherries may influence the sustainable choices made by both merchants and consumers. The sustainable choice is defined in the present context as representing a rule or a set of rules, applied systematically for supporting a decision or a set of decisions based on existing scientific evidence.

Sweet cherry (*Prunus avium* L.) cultivars are harvested in December and January in the Southern Hemisphere, "as this harvest time coincides with lucrative markets such (North America, Southeast and East Asia, Western Europe)"; are "in high demand in the late spring and early summer" because they are first on the fresh market; dominate the market when their fruit are red, "while cultivars of blush, white, or yellow colour are in less demand"; "mature from the end of April (in southern growing regions) to June-July (main season)" in temperate zones of the Northern Hemisphere, "while the picking season finishes in late August in Norway"; ripen first among stone fruits; span a long maturity period (Bujdoso et al., 2017).

The story about the measurements of the varieties started with the study carried out on seven cherries different varieties collected from their specific area, respectively Southwestern part of Romania, County of Timis. The cherry varieties studied according to the area of origin were: 'Ulster' (Variety 1), 'Kordia' (Variety 2), 'Rosii de Bistrita' (Variety 3), 'Bigarreau' (Variety 4), 'Black Star' (Variety 5), Royal Lady' (Variety 6), 'Wista' (Variety 7).

For the seven varieties, we selected two physical characteristics and two for quality. One of the two quality characteristics is also physical, but this is the most important physical characteristic sought especially by merchants, but also by consumers. For each of the seven varieties we chose normal fruits, in number of 25 per variety, which we later analysed for each variety, the four characteristics. The fruits have been collected for examination at their optimal ripening stage, eliminating the hit, misshapen, uneven fruits, or anything else that is determined by an accident, and not by a variety characteristic.

The characterization of the cherry fruits involved the determination of their height, diameter, firmness and the soluble substance (sugar content). The measurable elements were calculated using the digital caliper (Insize-1108, Loganville, GA, USA; unit: mm), the firmness was determined using the fruit hardness tester (Lutron FR-5105, unit: g/cm^2). The soluble substance (% Brix) was determined using the Atago Pal 3870 (Tokyo, Japan) portable refractometer. All these determined characteristics can be found in Appendix 1, at the end of the present paper, and their averages are introduced in Table 1.

The physical characteristics selected for analysis are the diameter and height of the fruit, while the quality traits are the firmness, which is a physical feature still one of the most important quality traits, and the soluble substance, which is indicative of the sugar content.

Table 1. Averages of the 4 characteristics of the 7 varieties analysed

Variety	Height (mm)	Diameter (mm)	Firmness (g/cm^2)	Sol. Substance (% Brix)
Average 1	23.49	25.58	408.4	20.16
Average 2	24.42	25.01	231.96	16.26
Average 3	22.63	25.07	231.68	14.75
Average 4	20.79	23.63	448.64	14.93
Average 5	22.72	24.42	398.8	18.75
Average 6	22.84	25.91	289.6	11.28
Average 7	23.82	28.29	374.2	23.89

Source: Own measurements and determinations.

The seven varieties investigated were screened for the four features and subsequently paired for determining the correlation coefficients, as following: diameter and firmness, diameter and soluble substance, height and firmness and respectively height and soluble substance.

Regarding the analyses of the physical characteristics and quality traits of the seven varieties, based on the data provided, including height, diameter, firmness and percentage of soluble substances (%Brix), we may notice that the variation between varieties is relatively small (a maximum difference of 3.63 mm), indicating a relatively similar size overall. No variety is distinguished by a particularly different size. Most varieties are close to a height of about 23 mm.

Height, being a fundamental physical characteristic, influences the visual appearance of varieties and can play a role in consumption preferences (such as handling, processing or presentation). Larger varieties, such as Variety 2 and Variety 7, may be perceived as more imposing or visually appealing in a market context.

In terms of diameter, there is a greater variation in diameter in relation to height (a maximum difference of 4.66 mm). Variety 7, with a much larger diameter, could be more imposing, while Variety 4, with the smaller diameter, is probably more compact.

Diameter is a key factor for the overall appearance and weight of varieties. A wider variety, such as Variety 7, could be perceived as having better value for the consumer, or more suitable for certain types of processing (such as wider cuts or slices). On the other hand, Variety 4, with its smaller diameter, could be suitable for uses requiring smaller or more concentrated products.

For firmness, we concluded that it varies widely, with some varieties (such as Variety 4 and Variety 1) exhibiting much higher firmness than others (Variety 3 and Variety 2). This suggests a marked difference in the texture or consistency of the varieties, which could be related to the maturity, density, or even freshness of the varieties measured.

Firmness is an important parameter for industrial processing and consumption. Varieties with higher firmness (such as Variety 4 and Variety 1) may be preferred for preservation or processing (e.g., slicing or cutting). On the other hand, softer varieties (Variety 3 and Variety 2) might be more suitable for immediate consumption or products that require a softer texture.

Concerning the soluble Substances, there is a very large variation in the percentages of soluble solids. Variety 7, with a content of 23.89% Brix, is by far the sweetest, while Variety 6, with 11.28% Brix, is the least sweet. These measurements are often used to assess the sugar content, which is crucial for the taste perception of fruit.

Varieties with high soluble contents, such as Variety 7 and Variety 1, are probably more popular for direct consumption due to their sweetness. Variety 6, with its much lower Brix content, may be less appealing to those seeking a sweet taste experience, but could have other industrial uses, such as for juices or processed products where the sugar can be adjusted.

Below we enclosed a comparison between the lowest and highest averages for each parameter.

The difference between the smallest and largest heights is 3.63 cm, which is a moderate variation. Variety 4 is about 15% smaller than Variety 2, the largest. This indicates that while the difference is noticeable, it is not extreme, suggesting that the varieties remain relatively comparable in terms of height.

In terms of diameter, the difference is 4.66 cm, or about 20%. Variety 7, with a much larger diameter, could be perceived as bulkier or more robust compared to Variety 4, the smallest in diameter.

Regarding firmness, there is a very significant difference here, with Variety 4 being almost twice as firm as Variety 3 (a difference of 216.96). This variation could reflect drastic differences in the texture of the varieties, with the firmer variety being more robust or dense, while the softer variety might be easier to bite or cut.
For soluble substances, the difference is very marked, with Variety 7 having a soluble substance content more than twice that of Variety 6 (12.61 difference). This suggests that Variety 7 is much sweeter or has a much higher dry matter content, which could make it more popular for consumption as a fresh fruit. Conversely, Variety 6 could be less sweet.
The most noticeable differences appear in terms of firmness and soluble substance content. Variety 4 and 7 are distinguished by extreme characteristics: Variety 4 is very firm and small, while Variety 7 is larger, with a larger diameter and a very high soluble substance content. Variety 6, on the other hand, is the opposite in terms of soluble substance content, with a much lower level.
We may conclude that this data shows that each variety has unique characteristics that influence their optimal use, whether for direct consumption, industrial processing or other specific applications. Varieties with larger heights and diameters, with high levels of soluble substances, will probably be preferred for fresh consumer markets. While firmer or less sweet varieties can have specific uses depending on their other physical qualities and texture.
The selection of tests identified the Kendall Tau b test as the most suitable approach for investigating the correlation coefficients between the paired physical characteristics and quality traits of the seven cherry varieties under consideration. The option pertains to the relatively limited number of fruits from each variety that were subjected to the selected characteristics, thereby enabling the extension of the number of varieties encompassed in the analysis. The pairs of features as introduced above were tested for the correlation coefficients using the selected test Kendall Tau b employing the SAS for Academics software platform and the results are presented and interpreted in the section bellow.

Figure 1. Cherry analysed varieties (from top left to bottom right, reading left to right: Var. 1, Var. 7, Var. 2, Var. 6, Var. 3, Var. 4, Var. 5)
(Source: Own determination and framing)

RESULTS AND DISCUSSIONS

The results of the first enquired pair of features respectively the potential link between the diameter and the firmness returns systematically p values above 0.05 indicating that null hypothesis cannot be rejected and therefore the correlation coefficients are irrelevant in the case of the analysed pair. The results are introduced in the Table 2 displaying the (absence of) correlation results for diameter and firmness using the Kendall Tau b correlation test.

Table 2. Correlation results for diameter and firmness using the Kendall Tau b correlation test

Firmness / Diameter	Value	Variety
Correlation coef.	0.14141	1
p value	0.3258	1
Correlation coef.	-0.01675	2
p value	0.9070	2
Correlation coef.	0.10385	3
p value	0.4687	3
Correlation coef.	-0.0802	4
p value	0.5749	4
Correlation coef.	-0.02007	5
p value	0.8885	5
Correlation coef.	-0.10385	6
p value	0.4687	6
Correlation coef.	0.06020	7
p value	0.6740	7

Source: computation of own determined data using SAS for Academics

Although a strictly physical approach could suspect that a larger diameter implies and lower firmness or the other way around, the seven screened varieties, the links between the two features has no statistical relevance and the correlation cannot be established.

Similar results are recorded testing for correlation the next paired features, firmness and height, where the *p* value for all the varieties systematically indicates that the null hypothesis cannot be rejected.

The results for all the tested varieties are introduced in Table 3 below where the correlation results, irrelevant for the purpose of the examination and the *p* values are presented.

Table 3. Correlation results for height and firmness using the Kendall Tau b correlation test

Height / Firmness	Value	Variety
Correlation coef.	0.13423	1
p value	0.3496	1
Correlation coef.	-0.06365	2
p value	0.6570	2
Correlation coef.	0.12395	3
p value	0.3871	3
Correlation coef.	-0.09015	4
p value	0.5282	4
Correlation coef.	0.01669	5
p value	0.9070	5
Correlation coef.	-0.22074	6
p value	0.1230	6
Correlation coef.	0.09683	7
p value	0.4981	7

Source: computation of own determined data using SAS for Academics

The results indicate that no correlation can be established between the height and the firmness of the fruits although, just like in the case of the diameter, the logic could suspect a link between the two features.

The situation regarding the results presents itself different when analysing the diameter and the soluble substance as screening for the sugar content. The results of the correlation test introduced in Table 4 indicate that for the Varieties 1, 2 and 5 we can reject the null hypothesis while for the remaining varieties the null hypothesis cannot be rejected. This reads as relevant correlation coefficients for the above-mentioned varieties while in the case of the others no link can be established between diameter and sugar content. Reading the correlation coefficients translates into an acceptable correlation since the values of the three varieties are all placed in the range 0.25-0.50, respectively 0.44 for Variety 1, 0.46 for Variety 2 and 0,56 for Variety 5. Although the last variety, the number 5, has a correlation coefficient higher than 0.50 could qualify for a moderate correlation, the determined value is too close to the boundary to interpret it as belonging to the upper category and relatively close to the other values to segregate them. The Varieties 3, 4, 6 and 7, are outside the correlation discussion given the high *p* values returned when compared in pairs.

Table 4. Crrelation results for diameter and soluble substance using the Kendall Tau b correlation test

Diameter / Sol. subst.	Value	Variety
Correlation coef.	0.44857	1
p value	**0.0019**	**1**
Correlation coef.	0.46723	2
p value	**0.0012**	**2**
Correlation coef.	0.23490	3
p value	0.1017	3
Correlation coef.	0.17696	4
p value	0.2157	4
Correlation coef.	0.56326	5
p value	**<.0001**	**5**
Correlation coef.	0.24284	6
p value	0.0920	6
Correlation coef.	0.13468	7
p value	0.3494	7

Source: computation of own determined data using SAS for Academics

Pairing and testing the height and the soluble substance for the correlation coefficients returns the results displayed in Table 5 for the seven selected varieties.

Table 5. Correlation results for height and soluble substance using the Kendall Tau b correlation test

Height / Sol. subst.	Value	Variety
Correlation coef.	0.54792	1
p value	**0.0001**	**1**
Correlation coef.	0.33278	2
p value	**0.0206**	**2**
Correlation coef.	0.24162	3
p value	0.0923	3
Correlation coef.	0.34667	4
p value	**0.0151**	**4**
Correlation coef.	0.57915	5
p value	**<.0001**	**5**
Correlation coef.	0.15489	6
p value	0.2819	6
Correlation coef.	0.05714	7
p value	0.6909	7

Source: computation of own determined data using SAS for Academics

Reading the correlation coefficients translates into an acceptable correlation since the values of the three varieties are all placed in the range 0.25-0.50, respectively 0.44 for Variety 1, 0.46 for Variety 2 and 0.56 for Variety 5.

Although the last variety, the number 5, has a correlation coefficient higher than 0.50 could qualify for a moderate correlation, the determined value is too close to the boundary to interpret it as belonging to the upper category and relatively close to the other values to segregate them. The Varieties 3, 4, 6 and 7, are outside the correlation discussion given the high *p* values returned when compared in pairs.

Pairing and testing the height and the soluble substance for the correlation coefficients returns the results displayed in Table 5 for the seven selected varieties. Like the examination for diameter and soluble substance, the Varieties 1, 2 and 5 return p values under 0.05 allowing the rejection of the null hypothesis and weighting the correlation coefficients. To these three variables a fourth one, the Variety 5, is added indicating that four out of the seven analysed varieties can display links between the analyse features for correlation. The strength of the correlation splits between acceptable correlation for the Varieties 2 and 4, and moderate correlation for the Varieties 1 and 5. The correlation coefficients for the moderate correlation are near the lower boundary and can be rather read as acceptable-moderate correlation.

The highest physical measurements are systematically recorded for the Variety 7, however the physical characteristics are not linked to the quality traits and no correlation can be established between them.

The analysis concerns the correlation links between the features and not the causality relations. In the case of the Variety number 6 analysed, the records for the soluble substance are the poorest among all varieties in absolute values and the firmness is the third lowest. With the second average largest diameter the Variety 6 is a good proof of lack of linkage between physical and quality traits. Varieties 1, 2, and 4, most likely as results of the breeding enhancements demonstrate an acceptable to moderate correlation for the soluble substance, respectively sugar content, with Variety 5 adding a moderate correlation for height yet not for diameter. The Variety 3 although acceptable for physical appearance for both diameter and height has low values recorded for firmness and soluble substance.

CONCLUSIONS

A correlation can be established between the physical characteristics of the fruits and their quality traits for selected varieties. Although the correlation coefficients do not indicate a strong correlation yet rather a moderate or acceptable one there is evidence indicating that certain physical features and quality traits are linked. The research question aimed to identify and measures these links, if existing, and make use of them in supporting the choice of both merchants and customers. Since a larger diameter or height does not necessarily means a larger amount of sugar or soluble substance, as the absence of correlation for richest analysed Variety (number 7) demonstrates, diameter cannot be used as a quality indication and cannot support the choice of either merchants or final consumers. The firmness, a quality trait of high importance for the merchants with direct impact on the shelves time and for the consumers as they can verify it and usually opt for a higher firmness as sign of a longer durability, is acceptable correlated for three of the analysed varieties. Similar to the diameter, the physical expression of the height is equally not a visual indication of any quality traits *per se*. Varieties with good physical records still uncertain and variating quality traits might still pass as a good choice for consumers. Perception could win as result of the visual impact of large fruits still there is no proof of any stable quality traits linked to the respective appealing fruits. The physical appearance of the cherries cannot represent an element that supports the sustainable choice of merchants or consumers when the quality of the cherries is a priority.

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Appendix 1. Dataset of physical characteristics and quality traits measurements of the seven selected varieties

Variety	Height (mm)	Diameter (mm)	Firmness (g/cm²)	Sol. Substance (% Brix)
Average 1	23.49	25.58	408.40	20.16
Average 2	24.42	25.01	231.96	16.26
Average 3	22.63	25.07	231.68	14.75
Average 4	20.79	23.63	448.64	14.93
Average 5	22.72	24.42	398.80	18.75
Average 6	22.84	25.91	289.60	11.28
Average 7	23.82	28.29	374.20	23.89

Source: own measurements.