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(Research Article)

Statistical analysis of biometric indicator values for the fruit of certain indigenous peach genotypes

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Abstract

Peaches are prized both for their organoleptic qualities and for their high nutritional value. Traditional methods of assessing fruit quality, such as manually checking firmness by pressing, are subjective and destructive, as they can affect the integrity of the fruit and, consequently, its commercial value. Compared with these conventional methods, non-destructive assessment technologies offer a rapid, accurate and non-invasive alternative for determining the internal and external characteristics of peaches. The implementation of these technologies helps to improve the grading and quality control process, reduces labour requirements and minimises mechanical damage to the fruit during inspection. In this context, indigenous peach genotypes, which are adapted to the soil and climate conditions in Romania, represent a valuable genetic resource for the study of natural resistance to diseases and abiotic stress factors. The evaluation of these genotypes enables the identification of traits of interest for programmes aimed at the improvement and conservation of genetic resources. In this study, a group of indigenous peach varieties was analysed in terms of the main biometric characteristics of the fruit. The genotypes that performed best were utilised in genetic improvement programmes, particularly to develop varieties with increased resistance to Plum pox virus (PPV).

Keywords: Peach; Resistance; *Prunus*; Symptoms; Soluble Dry Matter

1. Introduction

The peach (*Prunus persica* (L.) Batsch) is native to China, the world's leading producer of peaches, with an annual output exceeding 15 million tonnes [1]. Peaches are prized not only for their sweet taste and juicy texture, but also for their high nutritional value, being an important source of polyphenols, soluble sugars, organic acids and vitamins. Despite these benefits and the introduction of improved varieties, global per capita consumption of peaches has been steadily declining over recent decades [2]. Research shows that this decline in consumption is mainly due to issues relating to fruit quality, such as harvesting before optimal ripeness, overripening, the occurrence of physiological disorders during the post-harvest period, and mechanical damage caused during handling and transport. The quality of peaches is defined both by external characteristics, such as size, shape, colour, flavour and the presence of surface defects, and by internal properties, including flesh firmness, sugar content, acidity, vitamin C levels and any internal defects. All these factors directly influence consumer perception and the degree of market acceptance [3]. Consequently, the commercial value of peaches is closely linked to their quality. For this reason, the development of rapid, accurate and efficient inspection technologies for assessing the quality of peaches represents a particularly important area of research, contributing both to increasing the competitiveness of horticultural products and to the sustainable development of the agricultural sector, as well as to maximising the market value of the fruit. Peaches are prized both for their organoleptic

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qualities and for their high nutritional value. Traditional quality assessment is frequently based on methods such as visual and olfactory evaluation or manual testing of firmness by pressing the fruit. However, these techniques are subjective, destructive and dependent on the operator's experience, as they can affect the integrity of the fruit and, consequently, its commercial value [4]. Traditionally, quality control is carried out by specialist inspectors, who assess the external appearance, aroma, texture and other sensory characteristics to determine the quality of the peaches [5]. Although these methods are widely used, they have numerous limitations: they are time-consuming, labour-intensive and involve significant operational costs. Furthermore, the variability of human assessments reduces the objectivity and reproducibility of the results, making them difficult to apply in industrial-scale sorting and inspection processes. In this context, non-destructive assessment technologies have emerged as a modern and efficient alternative for determining the quality of peaches [6]. These methods enable the rapid and accurate characterisation of the physical and chemical properties of the fruit without compromising its integrity. Non-destructive techniques can be used to assess both the external and internal characteristics of peaches, helping to improve sorting and quality control processes. At the same time, these technologies reduce reliance on human assessment, minimise labour requirements and limit mechanical damage to the fruit, thereby providing a reliable solution tailored to the demands of modern production and marketing [7]. The application of non-destructive assessment technologies in peach quality control contributes significantly to reducing labour costs, particularly in the case of inspections carried out on an industrial scale, where conventional methods require a large number of inspectors. Through the use of automated systems capable of carrying out rapid and accurate assessments, reliance on specialised staff is considerably reduced, leading to a more efficient use of human resources. At the same time, the implementation of these technologies improves the consistency of the assessment process, enhances the quality of products intended for sale, and provides the agricultural sector with a modern, efficient and reliable solution for monitoring fruit quality, representing a significant advance in the field of agricultural technologies [8]. Although numerous studies on the use of non-destructive methods for assessing fruit quality have been published in the specialist literature, there is no comprehensive review dedicated exclusively to their application to peaches.

This analysis aims to provide a systematic overview of the main technologies used for the non-destructive testing of these fruits. The first part presents the operating principles of the most important methods, such as visible and near-infrared spectroscopy (Vis/NIR), machine vision systems, hyperspectral imaging (HSI), the determination of dielectric and optical properties, fluorescence spectroscopy, the electronic nose and tongue, as well as methods based on acoustic vibrations. Subsequently, the results obtained by researchers in the use of these technologies for assessing ripeness, quality grading, disease detection and other relevant applications in the field of peach quality control are analysed and summarised [9]. Next, the main types of data generated by each technology are presented, together with the specific methods for processing and interpreting them, and the characteristic stages of the detection process are illustrated. Finally, the advantages and limitations of each method are critically analysed, the challenges involved in their implementation are highlighted, and future research directions are discussed. Through this approach, the analysis aims to provide a useful framework both for the development of future research and for the expansion of the practical applications of non-destructive technologies in the quality assessment of peaches.

2. Material and methods

2.1. Plant material

The peach genotypes ("Crevedia", "Floarea", "Armonie", "Nuca", "Ștef", "Dundi", etc.) originating from the south of the country were identified as plant material. (Figure 1 and 2)

2.2. Methodology

Assessing the ripeness of peaches is of great importance, as it can have a significant impact on the optimal harvest time for fresh peaches. The fruit was weighed using analytical balances and analyzed using an Ak 2400 spectroscope. The results were statistically analyzed using an ANOVA test.

(source/original)

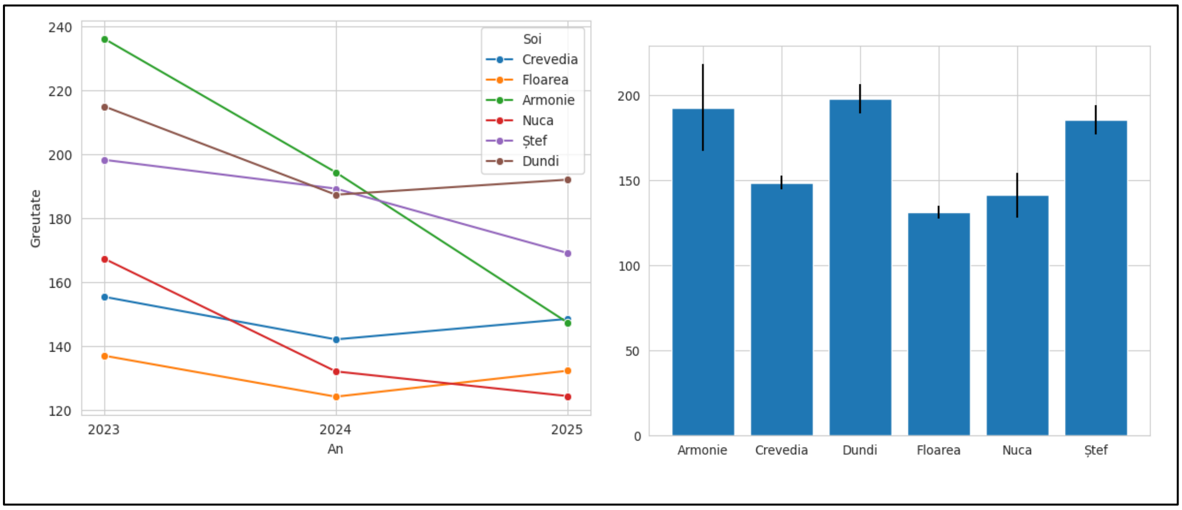
Figure 1 and Figure 2 Selected peach varieties Dundi and Armonie

The weight of peaches varies depending on the variety, but in general, peaches are considered large or medium to large. Many varieties produce fruit weighing between 120 and 180 grams. Some trees can produce even larger fruit, weighing 200–300 grams, according to some plant growers. Thus, the heaviest fruit was recorded for the **Armonie** variety at 236.14 g, followed by the **Dundi** variety at 215.00 g, then the 'Șef' variety at 198.30 g, whilst the lowest values were recorded for the 'Floarea' variety at 137.11 g, followed by the 'Crevedia' variety at 155.50 g, in 2023. (Table 1.)

Table 1 Results of biometric characterizations of the fruit in the studied peach varieties

Nr. CRT	Genotyps	The weight of the fruit (g)/2023	The weight of the fruit (g)/2024	The weight of the fruit (g)/2025
1.	Crevedia	155.50	142.2	148.6
2.	Floarea	137.11	124.3	132.4
3.	Armonie	236.14	194.4	147.5
4.	Nuca	167.42	132.2	124.5
5.	Ștef	198.30	189.3	169.2
6.	Dundi	215.00	187.4	192.1

In 2024, the highest fruit weight was recorded for the Armonie genotype at 194.4 g, followed by the Ștef genotype at 189.3 g and the Dundi genotype at 187.4 g. In 2025, the highest fruit weight was recorded for the Dundi genotype at 192.1 g, followed by the Ștef genotype at 169.2 g and the Crevedia genotype at 148.6 g. The lowest value was recorded for the Nuca genotype at 124.5 g.



Statistici descriptive; Crevedia: 148,7 ± 6,7 g; Floarea: 131,3 ± 6,5 g; Armonie: 192,7 ± 44,2 g; Nuca: 141,4 ± 22,5 g; Ștef: 185,6 ± 14,8 g; Dundi: 198,2 ± 14,9 g.; Anual average: 2023 – 184,9 ± 36,5 g; 2024 – 161,6 ± 31,2 g; 2025 – 152,4 ± 25,5 g.

Figure 3 and Figure 4 Determination of the biometric characteristics of fruit in the studied peach varieties

ANOVA: The effect of the cultivar is highly significant ($F_{5,10} = 9.38$, $p = 0.001$), whereas the effect of the year does not reach the significance threshold ($F_{2,10} = 3.74$, $p = 0.061$), although a trend regarding weight is observed. The Tukey test (HSD = 47.8 g) identifies two homogeneous groups:

- Group A (large fruits): Dundi (198.2 g), Armonie (192.7 g), Ștef (185.6 g);
- Group B (small to medium fruits): Crevedia (148.7 g), Nuca (141.4 g), Floarea (131.3 g).

The Armonie cultivar exhibits the highest inter-annual variability (CV = 22.9%), dropping from 236.1 g (2023) to 147.5 g (2025), which suggests high sensitivity to climatic conditions. Dundi and Ștef maintain relatively constant high weights (CV 6.6–8.0%). (Figure 4 and 5)

The weight of a peach pit varies by variety, but generally, it accounts for a small proportion of the fruit's total weight. Peach pits can weigh between 2% and 10% of the fruit's weight, depending on the variety and the size of the fruit. Pit weight is not constant; it depends on the size and variety of the peach. Larger fruits tend to have pits that are proportionally smaller relative to the flesh, whereas smaller fruits may have pits that are larger in proportion.

There are differences between varieties regarding pit weight. Some varieties have larger or smaller pits relative to the flesh. Among the native genotypes studied, the highest pit weight values were recorded for the 'Floarea' variety (6.22 g, with a flesh-to-pit ratio of 4.53%), followed by 'Armonie' (5.25 g, with a ratio of 2.22%) and 'Crevedia' (3.91 g, with a ratio of 2.51%). The lowest values were recorded for the 'Dundi' variety (2.89 g, with a ratio of 1.34%) (Table 2).

Table 2 Results of Biometric Characteristic Analyses of Fruit in the Studied Peach Varieties/2023

Genotype	**Kernel weight (g)/2023**	**Pulp-to-seed ratio /2023(%)**
Crevedia	3.91	2.51
Ștef	3.47	1.74
Nuca	2.99	1.78
Armonie	5.25	2.22
Dundi	2.89	1.34
Floarea	6.22	4.53

Table 3 Results of measurements of the biometric characteristics of fruit in the studied peach varieties/2024

Genotip	Kernel weight (g)/2024	Pulp-to-seed ratio /2024(%)
Crevedia	3.91	1.91
Ștef	3.01	1.54
Nuca	2.89	1.25
Armonie	4.24	1.99
Dundi	2.34	1.22
Floarea	4.21	1.43

In 2024, the highest kernel weight was recorded for the 'Armonie' genotype, at 4.24 g, with a pulp-to-kernel ratio of 1.99%. This was followed by the 'Floarea' genotype, with 4.21 g and a pulp-to-kernel ratio of 1.43%. The lowest value was recorded for the 'Dundi' genotype, at 2.34 g, with a pulp-to-kernel ratio of 1.22%.

Table 4 Results of measurements of the biometric characteristics of fruit in the studied peach varieties/2025

Genotip	Kernel weight (g)/2025	Pulp-to-seed ratio /2025
Crevedia	2.92	1.52
Ștef	3.97	1.62
Nuca	2.69	1.24
Armonie	4.26	2.25
Dundi	2.74	1.24
Floarea	5.22	3.43

In 2025, the highest kernel weight was recorded for the 'Floarea' genotype, at 5.22 g with a pulp-to-kernel ratio of 3.34%, followed by the 'Armonie' genotype, at 4.26 g with a pulp-to-kernel ratio of 2.25%. The lowest fruit weight was recorded for the 'Nuca' genotype, at 2.69 g with a pulp-to-kernel ratio of 1.24%.

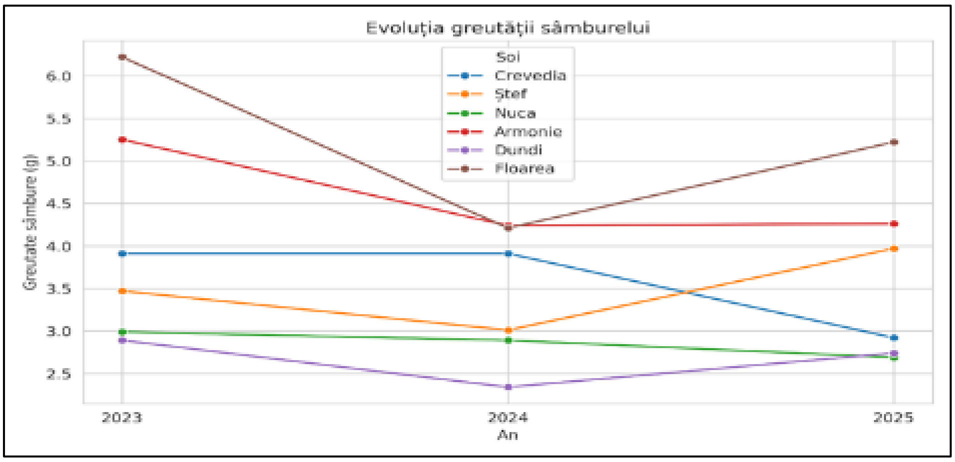


Figure 5 Results of the analyses of the biometric characteristics of the fruit in the studied peach varieties

Descriptive statistics:

- Cultivar: **Crevedia** 3.58 ± 0.57 g; Ştef 3.48 ± 0.48 g; Nuca 2.86 ± 0.15 g; **Armonie** 4.58 ± 0.58 g; **Dundi** 2.66 ± 0.29 g; **Floarea** 5.22 ± 1.01 g.
- Yearly mean: 2023 – 4.12 ± 1.33 g; 2024 – 3.43 ± 0.87 g; 2025 – 3.63 ± 1.02 g.
- ANOVA: Cultivar has a significant effect ($F_{5,10} = 14.97$, $p < 0.001$), whereas year does not ($F_{2,10} = 1.76$, $p = 0.221$). Tukey HSD (0.96 g) segregates the cultivars into:
- Group A (heavy kernels): Floarea (5.22 g), Armonie (4.58 g);
- Group B (light kernels): Crevedia (3.58 g), Ştef (3.48 g), Nuca (2.86 g), Dundi (2.66 g).

The **Floarea** cultivar stands out; although it produces small fruits (131.3 g), it possesses the heaviest kernel, which partially explains its low flesh yield. The **Dundi** and **Nuca** cultivars, with their small kernels, offer processing advantages.

Graphical analysis: The annual line graph (Figure 5) shows greater variability for Floarea (a decrease in 2024, an increase in 2025), whereas the other cultivars exhibit minimal fluctuations. The bar chart with letter annotations (Figure 5) highlights the distinct difference between Floarea/Armonie and the other genotypes.

The soluble solids content (SSC) in peaches varies depending on the cultivar and growing conditions, but generally ranges between 10% and 15%. A higher SSC indicates a greater concentration of sugars and other soluble substances, resulting in a sweeter taste and superior fruit quality. The SSC in peaches is frequently cited as falling within the 11% to 14% range. Growing conditions—such as sunlight exposure, temperature, and moisture levels—can influence SSC. Different peach cultivars may also exhibit varying SSC values; one study notes a range from 11.4% for a variant treated with fertilizers and organic treatments to 12.4% for an untreated variant.

Table 5 Results of analyses to determine the soluble dry matter content (%) of the fruit in the studied peach varieties / 2023, 2024, 2025.

Genotyps	Soluble dry matter (%)/2023	Soluble dry matter (%)/2024	Soluble dry matter (%)/2025
Crevedia	11.8	12.52	12.96
Ştef	12.9	11.79	12.01
Nuca	11.1	11.98	11.99
Armonie	10.3	12.28	12.81
Dundi	14.2	11.38	11.98
Floarea	11.9	14.56	15.42

Among the varieties studied in 2023, the highest soluble solids content (SSC) values were recorded for the 'Dundi' variety (14.2%), followed by 'Nuca' (12.9%). The lowest values were observed in the 'Armonie' variety (10.3%), followed by 'Floarea' (11.1%). Higher SSC is associated with better fruit maturity, more intense flavor, and a more pleasant texture. A refractometer can be used to determine the exact SSC of a specific batch of peaches. This easy-to-use instrument measures the refractive index of the fruit juice, which is then converted into the SSC value. In 2024, the highest value was recorded for the 'Floarea' genotype (14.56%), followed by 'Crevedia' (12.52%) and 'Armonie' (12.28%). The lowest value was recorded for the 'Dundi' genotype (11.38%). In 2025, the highest SSC value was recorded by the 'Floarea' genotype (15.42%), followed by the genotype with 12.96%. The lowest value was recorded for the 'Dundi' genotype (11.98%).

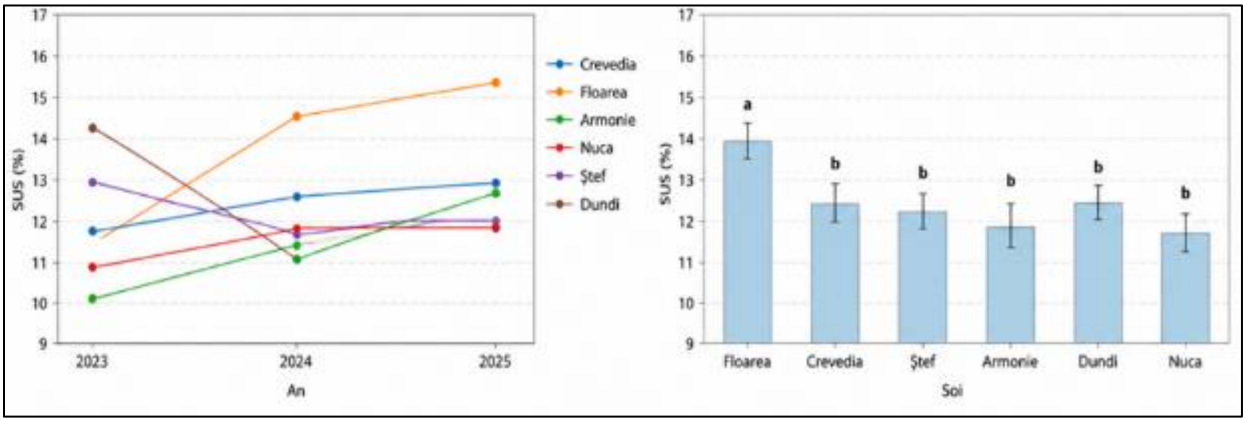


Figure 6 and Figure 7 Results of analyses to determine the soluble dry matter content (%) of the fruit in the studied peach varieties / 2023, 2024, 2025

Descriptive statistics

Cultivar: **Crevedia** 12.43 ± 0.60; **Ștef** 12.23 ± 0.59; **Nuca** 11.69 ± 0.51; **Armonie** 11.80 ± 1.33; **Dundi** 12.52 ± 1.50; **Floarea** 13.96 ± 1.94. (Figure 6 and 7)

Yearly mean: 2023 – 12.03 ± 1.49; 2024 – 12.42 ± 1.12; 2025 – 12.86 ± 1.43.

ANOVA: Cultivar did not differ significantly at the α=0.05 level ($F_{5,10}$ = 3.06, p = 0.062), and the year had no significant effect ($F_{2,10}$ = 1.68, p = 0.234). However, there is a trend towards differentiation: **Floarea** reached the highest mean value (14.0%), while the Nuca and Armonie cultivars showed the lowest (11.7–11.8%). High intra-cultivar variability (CV 4–14%) diluted statistical significance, but overall, the TSS content is satisfactory for all genotypes (>11%).

Variables showing a significant cultivar effect were subjected to the Tukey HSD test (α = 0.05) to identify homogeneous groups. Yearly means were used as replicates (n=3) for each cultivar.

Graphical analysis: The annual trends (Figure 6) show an upward trajectory for most varieties, with the exception of Dundi and Ștef, which hit a low in 2024. The Floarea variety stands out in 2024–2025, reaching 15.4% in 2025.

3. Conclusion

The **Armonie** variety exhibits the highest year-to-year variability (CV = 22.9%), dropping from 236.1 g (2023) to 147.5 g (2025), which suggests high sensitivity to climatic conditions. **Dundi** and **Ștef** maintain relatively constant, high weights (CV 6.6–8.0%).

Statistical analysis of kernel weight reveals greater variability for **Floarea** (a decrease in 2024 followed by an increase in 2025), whereas the other varieties show minimal fluctuations. The bar chart with significance letters (Figure 7) highlights the distinct difference between **Floarea/Armonie** and the other genotypes.

Statistical analysis regarding soluble dry matter shows an upward trend for most varieties, except for **Dundi** and **Ștef**, which recorded a minimum in 2024. **Floarea** stands out in 2024–2025, reaching 15.4% in 2025.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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