CHARACTERIZATION AND ASSESSMENT OF PHYSICAL AND MECHANICAL PROPERTIES OF ROSEHIP (*ROSA CANINA* L.) FRUITS AND SEEDS

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Abstract. Rosehip shrub, scientifically known as *Rosa canina*, grows wild in various regions of Romania, particularly in mountainous areas and deciduous forests. It is characterized by high genetic diversity, encompassing numerous genotypes and varieties adapted to local conditions. Rosehip fruit consists of pulp and seeds as its primary components, with each fruit containing approximately 30 seeds. In our study, we present a series of analyses conducted on the whole fruit, including individual mass, geometric dimensions, sphericity, mass of 1000 fruits, pulp-to-seed ratio, bulk density and hardness. Similar analyses were also performed on the seeds. For illustration, the individual mass of the fruits ranged from 0.68 to 1.36 g, while the bulk density varied between 0.60 and 0.75 g·cm^{-3}. The density of the fruits was between 0.72 and 0.93 g·cm^{-3}, and the mass of 1000 fruits was 1092.43 g. The force required for breaking the fruits ranged from 90.06 to 145.5 N. Regarding the seeds, the mass of 1000 seeds was 20.2 g, the pulp-to-seed ratio ranged from 1.26 to 3.44, and the seed density varied between 1.10 and 1.40 g·cm^{-3}. The pulp of the rosehip fruit is crucial for health, while the seeds, from which oil is extracted, are valuable due to their significant content of antioxidants, flavonoids, and fatty acids. The engineering properties of rosehip fruits are essential parameters for the effective design and optimization of systems, machinery, and processing technologies. Furthermore, this knowledge contributes to the improvement of post-harvest handling and the extraction of valuable components, such as oil and bioactive compounds, thereby maximizing the economic and health benefits of rosehip processing.

Keywords: rosehip fruits and seeds, dimensions, sphericity, hardness values.

Introduction

Rosehip (*Rosa canina* L.), a species of the Rosa genus in the Rosaceae family, is a valuable crop found in temperate and subtropical regions around the world. In Romania, as well as in other parts of Europe, Asia, and North America, rosehip is highly regarded for its exceptional nutritional and pharmacological value [1]. Wild rosehips thrive in diverse ecosystems, from forest edges to open grasslands, demonstrating their adaptability and importance in various industrial fields.

The fruit is widely used in food processing, herbal medicine, and cosmetics, making it a versatile and commercially significant natural resource. Rosehips, known as pseudofruits, are aggregates consisting of multiple achenes enclosed within a hypanthium, a developed floral cup, red in color and with a fleshy texture [2; 3]. The fruits typically weigh between 1.2 and 2.7 g, with lengths ranging from 14.0 to 28.8 mm and diameters of 13 to 20 mm. They consist of approximately 65-70% pericarp, the fleshy outer layer, which is rich in bioactive compounds and nutrients. The remaining 30-35% comprises hard, slightly hairy seeds, which are often removed during processing but can also be a source of oils and other valuable components [3; 4].

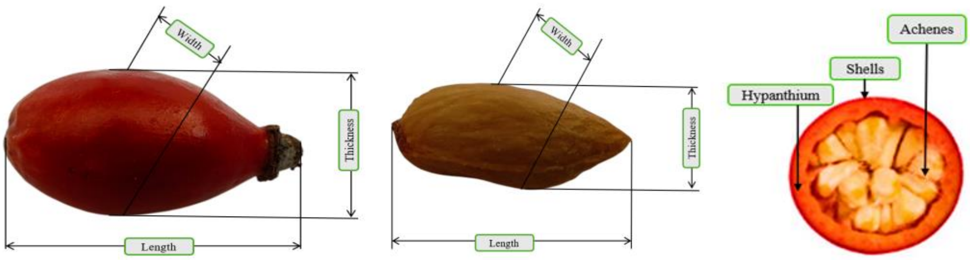

Fig. 1. **Measurement of the length, width, and thickness of the rosehip fruit and seed, as well as the fruit structural analysis**

Rosehip fruit is a rich source of essential minerals, including phosphorus, potassium, calcium, magnesium, iron, zinc, copper, and manganese. They are among the richest natural sources of vitamin C, containing an impressive 935 to 1230 mg per 100 g, surpassing most other fruits and vegetables in ascorbic acid content. In addition to their high vitamin C content, rosehip fruits are also rich in other essential vitamins, including A, B1 (thiamine), B2 (riboflavin), B6 (pyridoxine), D, E, and K,

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contributing to their exceptional nutritional profile. These fruits have a total phenolic content ranging from 290 to 1385 mg per 100 g, with catechin and procyanidin B2 being the predominant phenolic compounds. These bioactive compounds are closely linked to the fruit's high antioxidant activity, making rosehip a potent natural source of antioxidants [4; 5].

Rosehip's quick microbial development and senescence make it an extremely perishable food product [4]. To extend their shelf life, the fruits are dried at low temperatures to preserve their bioactive compounds and essential nutrients, including enzymes. Subsequently, grinding the dried fruits is the most practical alternative for consumption, which is otherwise limited to jams and infusions. The resulting powder can be utilized to enrich food products, such as dairy products, meat-based items, ice cream and beverages, with bioactive compounds. Additionally, this powder serves as a valuable ingredient in dietary supplements, pharmaceuticals, and cosmetic products. However, to effectively process these fruits, it is essential to first understand their physical and mechanical properties. This knowledge is crucial for selecting suitable milling and sieving equipment to produce powder with the desired particle size [3; 6].

Limited information is available regarding the physical and mechanical properties of rosehip fruits. Factors such as the hardness of the seeds, the moisture content of the fruit, and the adhesion properties of the pericarp can significantly influence the choice of the processing methods. Furthermore, gaining detailed insights into the fruits' structural integrity and their response to mechanical forces would significantly enhance the efficiency of milling processes. Such knowledge can help optimize grinding techniques to achieve finer and more uniform particle sizes, which are essential for improving the solubility, bioavailability, and stability of the resulting powder. In this context, beyond powder production, understanding the properties of the seeds is equally critical, as it plays a key role in optimizing the pressing process for oil extraction, ensuring maximum yield and preservation of the nutritional and bioactive qualities of the oil.

This study aimed to evaluate the geometric, physical, and mechanical properties of *Rosa canina* L. fruit and seeds, including mean diameter, sphericity, surface area, circularity, bulk and true density, porosity and hardness, to support applications in their processing.

Materials and methods

Material location

Rosehip fruits, of the *Rosa canina* variety, were collected from a forested region in the Râmnicu Vâlcea area, situated in the central-south part of Romania (latitude: 44°56'09", longitude: 23°49'14", altitude: 284 m, according to Google Earth version 10.57.0.4), in the first week of November. They were light red, completely ripe, and free of mold and other impurities. The fruits were brought to the laboratory and left at room temperature until they reached a moisture content of 32%, with all determinations to be made at this moisture content. Additionally, the seeds were manually separated from the pulp in order to determine their characteristics.

Determination of geometrical characteristics and physical properties

Dimensions of each rosehip fruit and seeds, including the length, width, and thickness, were measured in three orthogonal directions using a digital Vernier Caliper with an accuracy of 0.01 mm. A random sample of 100 fruits and seeds was selected for measurement to ensure the representativeness and reliability of the data. The following formula was used to calculate the mean diameters of fruits and seeds [7].

$$D_g = \sqrt[3]{L \cdot W \cdot T}, \quad (1)$$

$$D_a = \frac{a + b + c}{3}, \quad (2)$$

$$D_e = \sqrt[3]{\left(\frac{4S}{\pi}\right)}, \quad (3)$$

where D_g – geometric mean diameter in mm;
D_a – arithmetic mean diameter, mm;
D_e – diameter of equivalent sphere, mm;

L – length, mm;
W – width, mm;
T – thickness, mm;
S – external surface area of fruit and seed.

Elongation (or lengthening) is a concept employed to characterize the shape of a fruit and its seeds, such as those of the rosehip, based on the ratio of its primary dimensions. In the case of the rosehip, elongation refers to the ratio between the length, width, and thickness of the fruit. These ratios offer valuable insights into the degree of elongation or roundness of the fruit. To determine the horizontal (*Eh*) and vertical elongation (*Ev*) of the fruits and seeds, the following equations were used [7; 8]:

$$E_h = \frac{L}{W}, \tag{4}$$

$$E_v = \frac{W}{T}. \tag{5}$$

Sphericity (sph, %) refers to how closely the shape of a rosehip or rosehip seed approximates a perfect sphere. To determine the spherical coefficient, the following formula was used [7; 9]:

$$sph = \frac{Dg}{L} \cdot 100. \tag{6}$$

The external surface area (S, mm^2) of rosehip fruits and seeds can be calculated based on the geometric mean diameter using the following equation:

$$S = \pi \cdot Dg^2. \tag{7}$$

Projected area (PA) represents the area formed by the projection of the fruit or seed ont a flat surface. It can be calculated using equation (7) [10].

$$PA = \frac{\pi}{4} \cdot L \cdot W. \tag{8}$$

Circularity (C) of rosehip fruits and seeds was assessed based on the relationship between the projected area (PA, mm^2) and the perimeter (P, mm), according to equation (8). A perfectly circular shape of the fruits and seeds indicates the highest level of geometric symmetry in their structure, and a value close to 1 suggests a high degree of symmetry [9].

$$C = 4 \cdot \pi \cdot \frac{PA}{P^2}. \tag{9}$$

The formula for the volume of an ellipse Eq. (9) was used to determine the volume (V) of fruits and seeds that resembled geometric ellipses.

$$V = \frac{1}{6} \cdot \pi \cdot L \cdot W \cdot T. \tag{10}$$

Surface Closure Ratio (SCR) provides insight into how closely the shape of the fruit or seed approximates a perfect circle or ellipse. A value close to 1 suggests a more regular, circular, or elliptical shape, while lower values indicate greater irregularity. This metric is particularly useful for comparing the morphological characteristics of different genotypes of hawthorn fruits and seeds [9].

$$SCR = \frac{4 \cdot \mathrm{PA}}{\pi \cdot L \cdot W}. \tag{11}$$

Moisture content was determined according to the “Oven Drying Method in compliance with international standards”.

Bulk density is characterized as the mass of a fruit and seed sample per unit volume, accounting for the pore spaces within the sample. It is determined by calculating the ratio of the sample mass to its total volume [10].

True density of rosehip fruits and seeds can be determined using the toluene (C_7H_8) displacement method. This method involves immersing a known mass of fruits or seeds in toluene and measuring the volume of toluene displaced. The true volume (V_{true}) is calculated as the difference between the final volume (V_2) and the initial volume (V_1) of toluene. The true density (ρ_{true}) is then determined using the formula [11].

$$\rho_{true} = \frac{m}{V_{true}}, \tag{12}$$

where m – mass of the sample;
V_{true} – calculated as the difference between V_2 and V_1.

Porosity (ε) of the fruits and seeds was determined from the bulk and true densities, applying the following equation:

$$\varepsilon = 1 - \frac{\rho_{bulk}}{\rho_{true}} \cdot 100. \tag{13}$$

Individual mass of the fruits, as well as the mass of thousand fruits and seeds, was measured using an electronic balance with an accuracy of 0.001g.

The pulp-to-seed ratio for a hawthorn fruit is determined by manually separating the pulp from the seeds, followed by individually weighing the two components and calculating the ratio as the mass of the pulp divided by the mass of the seeds.

Hardness of rosehip fruits and seeds was determined using a Hounsfield/Tinius Olsen mechanical testing machine (model H1 KS). A total of 100 fruits and 100 seeds were tested, and the corresponding hardness force values were recorded using the integrated data acquisition system. The rosehip fruits and seeds were positioned along the horizontal axis during testing to ensure uniform load application and accurate hardness measurements. Data processing was done in Microsoft Excel 365.

Results and discussion

1.Physical and mechanical properties of rosehip fruit

All characteristics were determined on fruit samples with a moisture content of 32%. The data presented in Figure 2 highlight variations in fruit size, with the mean length recorded at approximately 19.70 mm, while the width and thickness showed slightly lower values of 11.61 mm and 11.56 mm, respectively. These dimensions indicate a relatively small and compact fruit structure.

Geometric properties, including the arithmetic mean diameter (Da) and geometric mean diameter (Dg), were calculated to provide insights into the overall shape of the fruit. The values for these parameters were recorded at approximately 14.29 mm and 13.82 mm, respectively. The sphericity index (sph) further confirms the degree of roundness, with an average value of 70.34%, suggesting that rosehip fruits tend to be more elongated than spherical.

Analysis of surface and volume-related parameters, including the projected area (PA), surface area (S), and volume, offers valuable insights into the physical structure of rosehip fruits. The projected area, with an average value of 180.66 mm², represents the two-dimensional footprint of the fruit, while the surface area, measured at approximately 604.07 mm², reflects the total external exposure. Additionally, the fruit volume, recorded at around 1.41 cm³, provides an estimate of its internal capacity, which is crucial for understanding its potential applications in processing and storage.

The values obtained for horizontal elongation (Eh) and vertical elongation (Ev) indicate significant differences in the morphology of rosehip fruits. Eh has an average of 1.70 ± 0.14, while Ev has an average of 1.00 ± 0.03, suggesting a tendency for the fruits to adopt an elongated shape in the horizontal plane rather than a spherical form. Circularity (C), with an average of 0.23 ± 0.01, confirms this trend, indicating a considerable deviation from a perfectly circular shape. Additionally, the constant value of the surface closure ratio (SCR), at 1.00 ± 0.00, reflects a fully enclosed surface, suggesting a well-defined and uniform shape. These characteristics are relevant for the morphological classification of the fruits and may influence both processing technologies and their applicability in the food and pharmaceutical industries. Then perimeter of the fruits was recorded at approximately 100.10 mm, further supporting the data on the overall size and shape of the fruits. These measurements provide valuable insights into the geometric and structural characteristics of the studied samples.

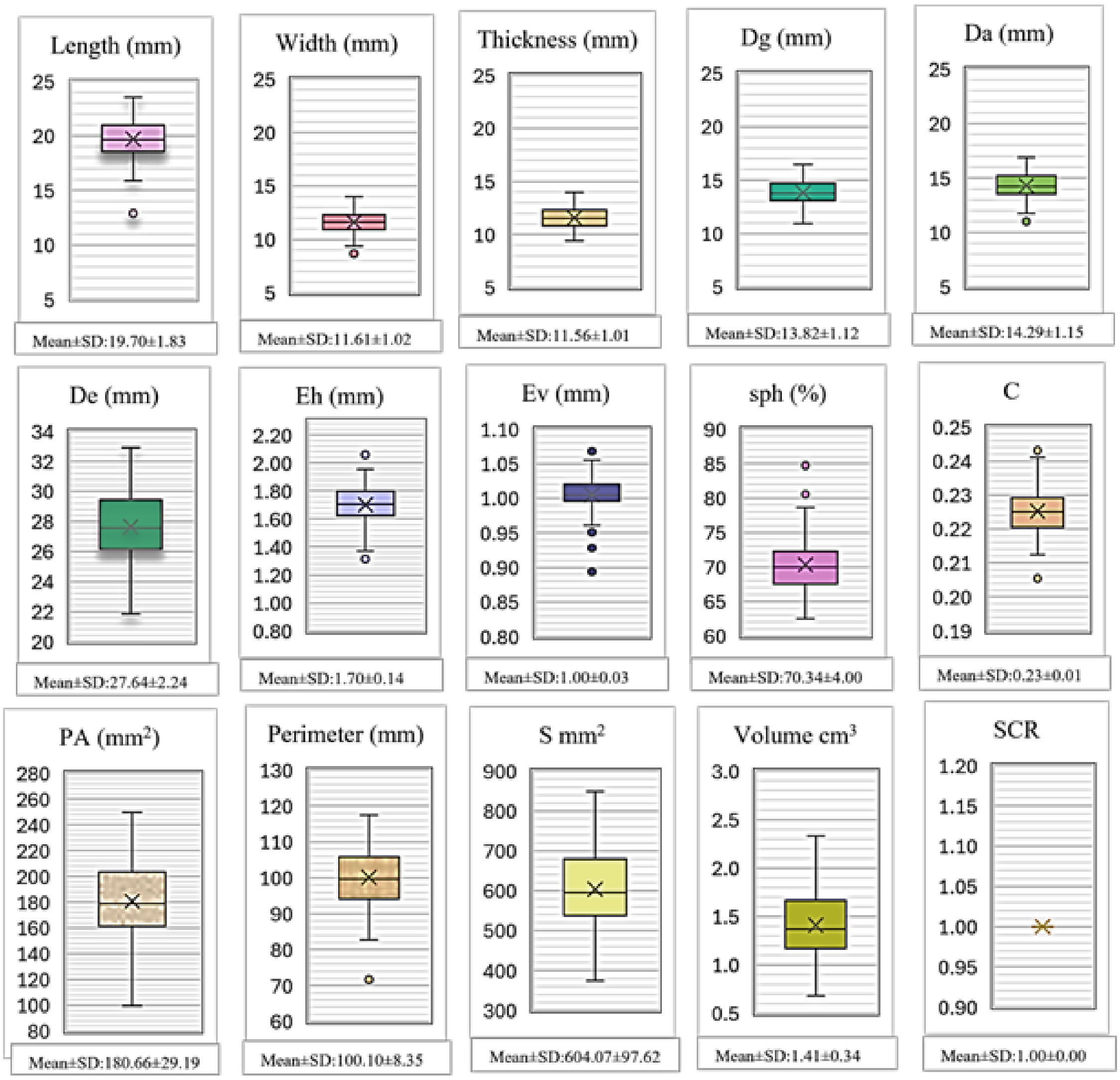

Fig. 2. **Morphological and dimensional characteristics of rosehip fruits**

The bulk density ranged from 0.60 to 0.75 g·cm^{-3}, while the true fruit density varied between 0.72 and 0.93 g·cm^{-3}. Porosity values were recorded between 16.66% and 19.35%. Individual fruit mass ranged from 0.68 to 1.36 g, and the mass of 1000 fruits was recorded as 1092.43 g. The pulp-to-seed ratio varied between 1.26 and 3.44. Hardness of rosehip fruits was determined using the force-deformation method, indicating the resistance force values between 90.06 and 145.5 N.

2.Physical and mechanical properties of rosehip seeds

The seeds exhibited a mean length of 5.14 mm, a width of 2.74 mm, and a thickness of 2.58 mm, indicating a small structure similar to a grain of wheat. The geometric mean diameter (Dg) and arithmetic mean diameter (Da) were determined to be 3.30 mm and 3.49 mm, respectively, providing relevant information on their dimensional distribution. These dimensions highlight the compact nature of rosehip seeds.

Horizontal elongation (Eh) of 1.91 mm, compared to the vertical elongation (Ev) of 1.07 mm, suggests that rosehip seeds are more susceptible to deformation in the horizontal direction than in the vertical one.The sphericity index (sph) presented an average value of 64.84%, suggesting a more elongated shape rather than spherical. The circularity factor (C) was 0.21, confirming the non-spherical form of the seeds.

The projected area (PA) of the seeds was 11.11 mm², with a perimeter of 25.41 mm. The surface area (S) was 34.53 mm², and the volume was 0.024 cm³, indicating the seeds' relatively low internal capacity. The surface closure ratio (SCR) was consistently 1.00, suggesting a closed surface structure.

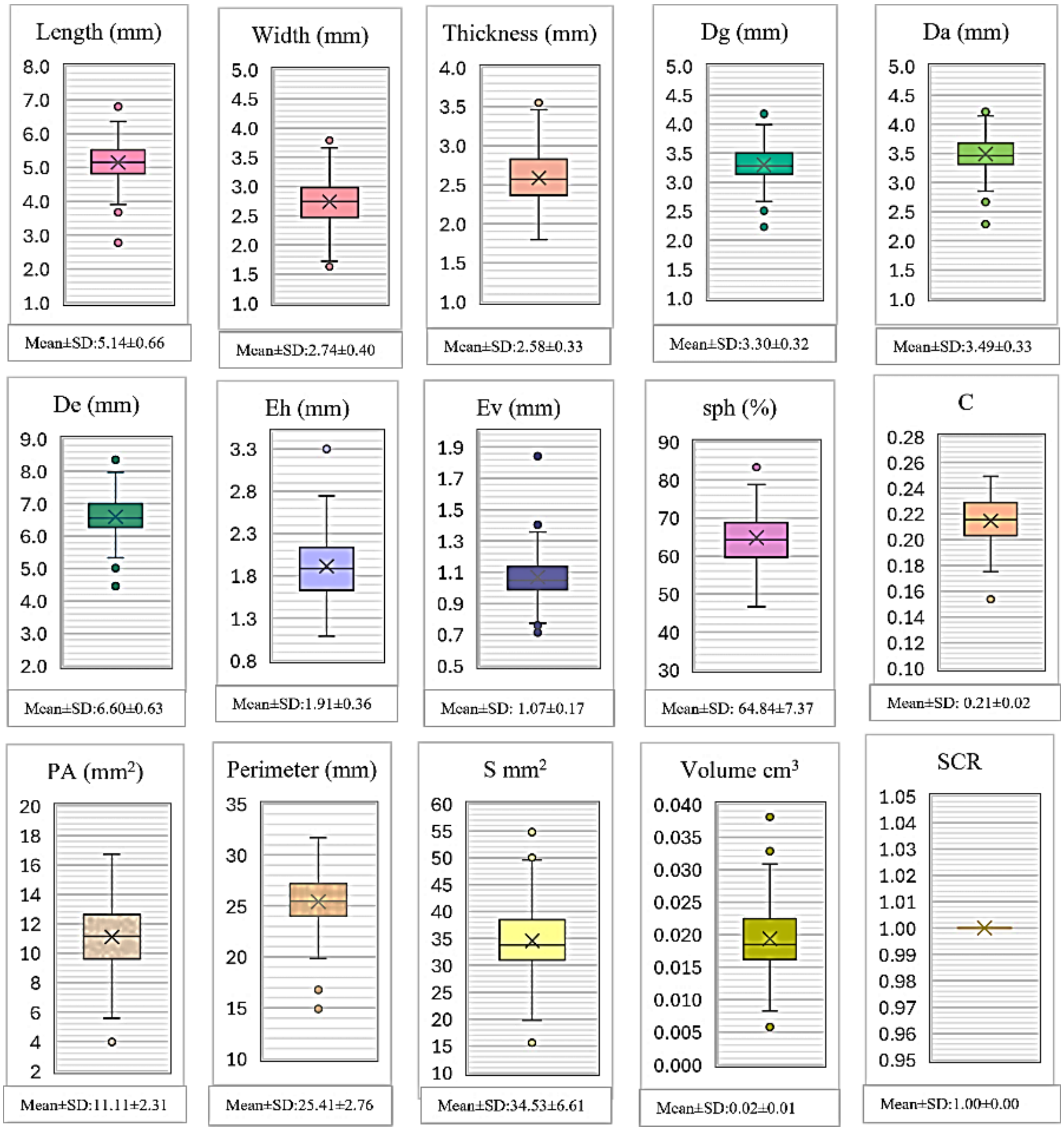

Fig. 3. **Morphological and dimensional characteristics of rosehip seeds**

For seeds, the bulk density ranged from 0.45 to 0.84 g·cm^{-3}, while the true density exhibited values between 1.10 g·cm^{-3}and 1.40 g·cm^{-3}. Consequently, the porosity value ranged between 40% and 59.09%. The variability in porosity values can be attributed to differences in seed morphology and structural arrangement, which influence intergranular spaces and the efficiency of compaction within the bulk material. Additionally, the mass of 1,000 seeds was 20.2 g. The seed resistance force varied between 36.8 N and 133.4 N. The marked variation in mechanical resistance reflects the heterogeneity of the seed coat and internal tissue composition, likely associated with genetic polymorphism or environmental conditions during the developmental phase.

Conclusions

1. Morphological analysis of rose hip components revealed distinctive geometric characteristics, with the fruits exhibiting moderate elongation (sphericity index 70.34%, circularity 0.23) and pronounced horizontal asymmetry (Eh = 1.70, Ev = 1.00), while the seeds demonstrated more pronounced elongation (sphericity index 64.84%, circularity 0.21) and a greater susceptibility to horizontal deformation (Eh = 1.91, Ev = 1.07), thereby establishing critical parameters for the development of selective size-based separation technologies that account for these structural particularities.

2. Significant difference in mechanical resistance between rose hip fruits (90.06-145.5 N) and seeds (36.8-133.4 N) reveals distinct hardness profiles and failure mechanisms, with seeds exhibiting considerably greater variability in compression response despite their smaller size. These findings provide essential parameters for calibrating crushing forces in processing equipment, aiming to achieve optimal component separation while preserving the integrity of bioactive compounds.

Author contributions

Conceptualization, V.G. and I.A.-D.; methodology, I.A.-D. and S.E.-M.; validation, V.G. and C.G.-A.; formal analysis, I.A.-D. and S.E.-M.; investigation, I.A.-D., S.E.-M., V.G. and C.G.-A.; data curation, V.G., S.E.-M. and C.G.-A.; writing – original draft preparation, I.A.-D.; writing – review and editing, I.A.-D. and V.G.; visualization, V.G. and C.G.-A.; project administration, V.G. All authors have read and agreed to the published version of the manuscript.

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