Physicochemical characterization of *Annona muricata* L., fruits in Jun^{2}n, Peru

Caracterización físicoquímica de frutos de *Annona muricata* L., en Junín, Perú

Caracterização físico-química dos frutos da *Annona muricata* L., em Junin, Peru

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Abstract

Soursop (*Annona muricata* L.) is an exotic fruit with high international demand, valued for its flavor, nutritional properties, and applications in the food industry. In Peru, its use includes fresh consumption and the production of pulp, nectars, and nutraceutical products. The objective of this study was to evaluate the physicochemical characteristics of fruits from selected soursop plants grown at the San Ramón Agricultural Experimental Station in the Department of Junín, Peru. The physical characteristics (fruit mass, polar and equatorial diameter), chemical characteristics (titratable acidity, ionic acidity, total soluble solids, and maturity index), as well as mineral content (phosphorus, magnesium, and calcium) were determined from the fruits. A completely randomized experimental design (CRD) and analysis of variance (ANOVA) were applied. The results showed that the FRCUNCP_09 and FRCUNCP_12 genotypes had the largest fruit mass (2.49 and 2.16 kg, respectively). On the other hand, the FRCUNCP_08, FRCUNCP_09, and FRCUNCP_12 genotypes presented optimal values of titratable acidity (0.8367, 0.9900, 1.1133), ionic acidity (3.99, 4.16, 3.62), and total soluble solids (16.5, 15.9, 17.7 °Brix), suitable for direct consumption and industrial processing. Regarding mineral content, FRCUNCP_09 had the highest concentrations of phosphorus (23.135 mg.100 g^{-1}) and calcium (6.200 mg.100 g^{-1}), while FRCUNCP_08 stood out for its magnesium content (21,604 mg.100 g^{-1}). It is concluded that these materials have potential for genetic improvement programs and the development of nutraceutical products.

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Resumen

La guanábana (*Annona muricata* L.) es una fruta exótica de gran demanda internacional, valorada por su sabor, propiedades nutricionales y aplicaciones en la industria alimentaria. En el Perú, su aprovechamiento abarca el consumo en fresco y en la elaboración de pulpas, néctares y productos nutraceúticos. El objetivo del estudio fue evaluar las características fisicoquímicas de frutos de plantas seleccionadas de guanábana cultivadas en la Estación Experimental Agropecuaria de San Ramón, Departamento de Junín, Perú. En los frutos se determinaron las características físicas (masa del fruto, diámetro polar y ecuatorial), químicas (acidez titulable, acidez iónica, solidos solubles totales e índice de madurez), así como, el contenido de minerales (fósforo, magnesio y calcio). Se aplicó un diseño experimental completamente al azar (DCA) y análisis de varianza (ANOVA). Los resultados mostraron que los genotipos FRCUNCP_09 y FRCUNCP_12 destacaron por la mayor masa del fruto (2,49 y 2,16 kg). Por otra parte, los genotipos FRCUNCP_08, FRCUNCP_09 y FRCUNCP_12 presentaron valores óptimos de acidez titulable (0,8367, 0,9900, 1,1133), acidez iónica (3,99, 4,16, 3,62) y sólidos solubles totales (16,5, 15,9, 17,7 °Brix), adecuados para el consumo directo y el procesamiento industrial. Con respecto al contenido de minerales, FRCUNCP_09 presentó las mayores concentraciones de fósforo (23,135 mg.100 g^{-1}) y calcio (6,200 mg.100 g^{-1}), mientras que FRCUNCP_08 destacó por su contenido de magnesio (21,604 mg.100 g^{-1}). Se concluye que estos materiales poseen potencial para programas de mejoramiento genético y desarrollo de productos nutraceúticos.

Palabras clave: fruto de guanábana, acidez titulable, acidez iónica, solidos solubles totales, minerales.

Resumo

A graviola (*Annona muricata* L.) é uma fruta exótica com alta demanda internacional, valorizada por seu sabor, propriedades nutricionais e aplicações na indústria alimentícia. No Peru, seu uso inclui o consumo in natura e na produção de polpa, néctares e produtos nutracêuticos. O objetivo deste estudo foi avaliar as características físico-químicas de frutos de plantas selecionadas de graviola cultivadas na Estação Experimental Agrícola de San Ramón, Departamento de Junín, Peru. As características físicas (massa do fruto, diâmetro polar e equatorial), características químicas (acidez titulável, acidez iônica, sólidos solúveis totais e índice de maturação), bem como o conteúdo mineral (fósforo, magnésio e cálcio) foram determinados a partir dos frutos. Um delineamento experimental inteiramente casualizado (DRD) e análise de variância (ANOVA) foram aplicados. Os resultados mostraram que os genótipos FRCUNCP_09 e FRCUNCP_12 se destacaram pela maior massa de fruto (2,49 e 2,16 kg). Por outro lado, os genótipos FRCUNCP_08, FRCUNCP_09 e FRCUNCP_12 apresentaram valores ótimos de acidez titulável (0,8367; 0,9900; 1,1133), acidez iônica (3,99; 4,16; 3,62) e sólidos solúveis totais (16,5; 15,9; 17,7 °Brix), adequados para consumo direto e processamento industrial. Em relação ao teor de minerais, FRCUNCP_09 apresentou as maiores concentrações de fósforo (23,135 mg.100 g^{-1}) e cálcio (6,200 mg.100 g^{-1}), enquanto FRCUNCP_08 destacou-se pelo teor de magnésio (21,604 mg.100 g^{-1}). Conclui-se que esses materiais apresentam potencial para programas de melhoramento genético e desenvolvimento de produtos nutracêuticos.

Palavras-chave: fruto da graviola, acidez titulável, acidez iônica, sólidos solúveis totais minerais.

Introduction

Soursop (*Annona muricata* L.) is experiencing a boom for its nutraceutical properties (Alomia-Lucero *et al*., 2022) and stands out among tropical fruits for its aroma. Soursop as a raw material can be used to make new products from its leaves and extracts, using technologies such as freeze drying and microencapsulation (Ávila de Hernández *et al*., 2012).

In Peru, soursop production exceeds 2,500 tons per year, with exports of 78 tons in 2023, mainly to Chile, the Netherlands, and the US, according to the Ministry of Agricultural Development and Irrigation (MIDAGRI, 2024). In Junín, the average production is 10 $t.ha^{-1}$, with Chanchamayo and Satipo standing out for their agroclimatic conditions (24-30 °C, 600-1250 meters above sea level). This region concentrates 8 to 10 % of national production and promotes agro-industrial development through the production of pulps and nectars (MIDAGRI, 2024).

More than 200 chemical compounds have been isolated and identified in soursop, with alkaloids, phenols, and acetogenins being the most important. Active compounds, such as acetogenins, have been shown to have inhibitory effects on cancer cell lines (Coria-Téllez *et al*., 2018).

Previous studies have investigated the variability in characteristics such as soluble solids, acidity, and pH, which are indicative of its quality and acceptance for consumption (Jiménez-Zurita *et al*., 2016). Similarly, there has been considerable interest in the context of crop adaptation to climate change (Kome *et al.,* 2024).

The chemical characterization of the fruits provides evidence of the genetic diversity present in the species, supported by the variability of sizes, shapes, and physicochemical attributes, such as soluble solids, acidity, and maturity ratio (Moreira *et al.,* 2018). In this context, the protein content in soursop pulp is comparable to that of economically important cereals, whose protein range generally varies between 7.8 % and 22.8 % (Tiencheu *et al*., 2021).

Soursop pulp has a total soluble solids content ranging from 13.0 to 17.0 °Brix and a pH between 3.00 and 4.00, reflecting an adequate balance between sweetness and acidity. These parameters meet the quality standards required for export, and if they do not meet the specifications of certain markets, they can be transformed into value-added products such as nectars, frozen pulps, or jams (Abdul Wahab *et al*., 2018). Studies carried out on soursop fruits originating from Nayarit, Mexico, reported soluble solids values between 7.1 and 20.1 °Brix (Jiménez-Zurita *et al*., 2016), as well as acidity levels ranging from 0.4 to 1.21 %.

Studies carried out by various authors confirm that soursop (*Annona muricata* L.) presents variability in its nutritional value, positioning it as a promising crop for agroindustry in tropical regions like Junín. Therefore, the objective of the study was to evaluate the physicochemical characteristics of fruits of selected soursop plants grown at the Agricultural Experimental Station of San Ramón in the Department of Junín, Peru.

Materials and methods

Study location

The study was carried out at the San Ramón Agricultural Experimental Station (E.E.A.R.), located in the province of

Chanchamayo, Department of Junín, Peru (11°07'16''S, 75°21'07''W, 854 m.a.s.l.). The climatic conditions of the area during the evaluation period were: maximum temperature between 23 °C and 26 °C, minimum temperature between 14 °C and 17 °C, and relative humidity between 68 % and 79 %. The average monthly rainfall ranged from 56 mm to 102 mm. Regarding the edaphic characteristics, the soil presented a sandy-loam texture and medium organic matter content.

Plant material

From a population of 70 six-year-old soursop plants (*Annona muricata* L.), sexually propagated and established under a 6 m x 6 m planting system, the evaluated plant material was selected, which consisted of 14 individuals with outstanding phenotypic characteristics in number of fruits (≥5 fruits.plant^{-1}), size (length ≥25 cm and diameter ≥18 cm), weight (≥3.5 kg per fruit) and health status. The selected plants were coded with the code FRCUNCP (from 01 to 14). Harvesting was carried out 125 days after flowering, a moment corresponding to the physiological maturity of the fruit. Four fruits per plant were harvested, from which physical characteristics (fruit mass, polar and equatorial diameter), chemical characteristics (titratable acidity, ionic acidity (pH), total soluble solids (°Brix degrees), and maturity index), and the content of phosphorus, magnesium, and calcium were determined.

To obtain the pulp, the fruits were washed, blanched (5 min), peeled, and pulped.

Determination of physical characteristics

To determine the mass of the fruits, a digital scale was used (Hanna, USA), while the polar and equatorial diameter measurements were performed with a digital vernier caliper (Mahr, Germany), following the characterization criteria according to the "List of descriptors for soursop" recommended by the Colombian Agricultural Research Corporation (CORPOICA, 2003), which considers the main characteristics of the fruit, in each corresponding state.

Determination of chemical characteristics

In the pulp of the soursop, the ionic acidity (pH) was determined, following the method established by the Association of Official Analytical Chemists (AOAC, 2016). For this purpose, a pH meter (EDGE Multiparametric, pH meter, Germany) was used, previously calibrated with buffer solutions. Subsequently, the electrode was introduced into the pulp sample until the stabilization of the value was reached, which was recorded as the final pH. The measurements were made in triplicate.

Titratable acidity was determined according to AOAC (2016), dissolving 10 g of pulp in 100 mL of distilled water. It was filtered, and a 10 mL aliquot was taken, to which three drops of phenolphthalein were added. The sample was titrated with 0.1 N NaOH until a pale pink hue was obtained. The measurements were made in triplicate. Titratable acidity values were expressed as mg citric acid.100g^{-1} sample.

Total soluble solids (°Brix degrees) were determined using a refractometer (HANNA, United States). First, the instrument was calibrated with a drop of distilled water, adjusting the reading to 0 °Brix. Then, a drop of the pulp filtrate was applied to the refractometer's prism in triplicate, and the corresponding values were recorded. Total soluble solids contents were expressed as °Brix.

Determination of mineral content

Phosphorus was determined following the AOAC method (2016). To do this, one (1 g) of pulp was weighed in triplicate and digested with concentrated HNO_3 in a microwave (Bosch, Germany) until a clear solution was obtained. The digested sample was diluted with distilled water and filtered. For the calibration curve, standard phosphate solutions were prepared using 1 mL of vanadate-molybdate solution at each standard and mixed. The reading was made in a spectrophotometer (Shimadzu, Japan) at 420 nm. The absorbance of the sample was compared with the calibration curve to determine the phosphorus concentration. The phosphorus concentration in the soursop pulp was expressed in mg.100 g^{-1} sample.

The concentration of magnesium and calcium was determined according to the AOAC method (2019), by atomic absorption spectrophotometry. To accomplish this, one (1) g of pulp was digested in triplicate with HNO_3 concentrated in a microwave (Bosch, Germany), then the sample was diluted with distilled water, filtered, and 1 % lanthanum chloride was added as a matrix modifier to eliminate possible interference in the reading. Standard solutions of Mg and Ca (0, 1, 5, 10, and 20 mg.L^{-1}) were prepared, and the absorbance was measured at 285.2 nm for magnesium and 422.7 nm for calcium in an atomic absorption spectrophotometer (Shimadzu, Japan). The concentration of Mg and Ca in soursop pulp was expressed in mg.100g^{-1} of sample.

Experimental design and statistical analysis

A completely randomized experimental design (CRD) was applied for the study, with three replications. The data obtained were processed using the SPSS software, version 26. An analysis of variance (ANOVA) and mean comparison tests were performed with a significance level of $p < 0.05$.

Results and discussion

Physical characteristics of soursop fruits

Table 1 shows the analysis of variance of the physical characteristics (mass, length, and diameter) of genotypes of soursop pulps (*Annona muricata* L.) evaluated in San Ramón, Junín.

Table 1. Analysis of variance of the physical characteristics (mass, length, and diameter) of soursop (*Annona muricata* L.) genotypes evaluated in San Ramón, Junín.

Genotypes	Length	Diameter	Mass
FRCUNCP_01	22.07±0.37b	14.05±0.15bc	2.14±0.01b
FRCUNCP_02	21.39±0.11c	13.40±0.20b-d	2.03±0.05c
FRCUNCP_03	19.89±0.41de	14.00±0.10bc	1.57±0.03f
FRCUNCP_04	21.25±0.15c	13.80±0.10bc	1.60±0.01ef
FRCUNCP_05	18.05±0.15h	13.05±0.85cd	2.04±0.03c
FRCUNCP_06	17.40±0.10i	11.65±0.25d	1.39±0.01g
FRCUNCP_07	18.60±0.10gh	14.35±0.25bc	1.37±0.01g
FRCUNCP_08	19.55±0.15e	13.50±0.20b-d	1.97±0.01c
FRCUNCP_09	27.65±0.25a	19.00±0.10a	2.49±0.09a
FRCUNCP_10	21.50±0.10bc	15.05±0.15b	2.17±0.01b
FRCUNCP_11	18.96±0.26fg	13.95±0.15bc	1.97±0.02c
FRCUNCP_12	20.30±0.10d	14.35±0.15bc	2.16±2.16b
FRCUNCP_13	17.06±0.26i	12.60±0.10cd	1.66±0.02e
FRCUNCP_14	19.47±0.14ef	14.30±0.20bc	1.86±0.04d

Different letters indicate statistically significant differences ($p< 0.05$)

The results obtained show that genotypes FRCUNCP_09 and FRCUNCP_10 presented the highest values of fruit mass. In contrast, genotypes FRCUNCP_06 and FRCUNCP_07 registered the lowest values. This behavior suggests that the size of the fruit is not always directly related to its mass because factors such as mesocarp density, peel thickness, and number of seeds also play a role (Villarreal-Fuentes *et. al*., 2020; Jiménez-Zurita *et al.,* 2017). In this regard, Villarreal-Fuentes *et. al*. (2020) indicate that these variations in fruit mass are related to genetic and morphological factors of the fruit and seed. Figure 1 shows the fruits that presented the highest mass in the plants evaluated: A) FRCUNCO_09 and B) FRCUNCO_10.

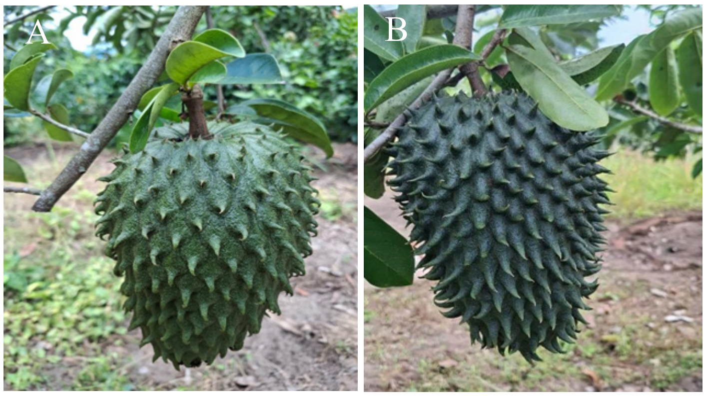

Figure 1. Fruits with the highest mass of the plants evaluated. A) FRCUNCO_09 and B) FRCUNCO_10.

Additionally, the variability in the mass and size of soursop fruits observed in this study can be attributed to genetic, phenological, and agroecological factors (Jiménez-Zurita *et al*., 2016). Fruit masses ranged from 1.37 to 2.49 kg, exceeding the values reported in Mexico and Nicaragua, countries in which fruits usually have masses between 0.4 and 1.0 kg, depending on the variety and production system (Abdul Wahab *et al*., 2018; Jiménez-Zurita *et al*., 2017; Nolasco-González *et al*., 2019; Villarreal-Fuentes *et al*., 2020).

Likewise, table 1 shows that genotypes FRCUNCP_09 and FRCUNCP_01 presented the largest dimensions, both in length and equatorial diameter, while FRCUNCP_06 and FRCUNCP_03 presented the lowest values. These results show a remarkable morphological variability between the genotypes evaluated, attributed to the sexual propagation of plants.

Chemical characteristics

Ionic acidity (pH)

Table 2 presents the mean values of ionic acidity (pH), titratable acidity, and total soluble solids (°Brix) obtained in the pulp of fruits of selected soursop genotypes in San Ramón, Junín.

The ionic acidity (pH) of the soursop pulp ranged from 3.59 (FRCUNCP_04) to 4.49 (FRCUNCP_07), values comparable to those reported by Jiménez-Zurita *et al*. (2017). This moderate acidity favors microbiological stability and allows its use in both fresh and processed products. A higher pH, such as that of FRCUNCP_07, improves sensory acceptance, but requires greater control in preservation, while a lower pH, such as that of FRCUNCP_04, is useful in inhibiting microbial growth. This variation is relevant to the stability and sensory acceptability of soursop-derived products.

The variability of pH in soursop pulps observed in this study is consistent with what was pointed out by Jiménez-Zurita *et al*. (2016), who attribute this variation to genetic and environmental factors, maturity state, agronomic practices (fertilization, irrigation, and pruning), fruit load, surface microbiota, and post-harvest management conditions, which modify the content of organic acids and the metabolism of the fruit (Fuenmayor *et. al.,* 2016). This characteristic is relevant for the microbiological stability of derived products. This variability is due, in part, to sexual propagation, which generates morphological and physicochemical diversity in the fruits. Therefore, the selection of plants with outstanding characteristics is essential for genetic improvement programs.

Table 2. Mean values of ionic acidity (pH), titratable acidity, and total soluble solids (°Brix) in the pulp of fruits of selected soursop genotypes in San Ramón, Junín.

Genotypes	pH	Acidity (%)	Total soluble solids (°Brix)
FRCUNCP_01	3.85±0.0058c	0.7667±0.0033b	15.0000±0.0577a
FRCUNCP_02	3.76±0.0058b	0.7933±0.0033c	14.4677±0.0333a
FRCUNCP_03	3.80±0.0058b	0.8800±0.0058e	15.5333±0.0333a
FRCUNCP_04	3.59±0.0058a	0.9033±0.0033f	13.1000±0.0577b
FRCUNCP_05	3.89±0.0058c	0.7500±0.0058b	14.0000±0.0577a
FRCUNCP_06	3.89±0.0116c	0.8800±0.0000e	14.8000±0.0577a
FRCUNCP_07	4.49±0.0153e	0.6600±0.0058a	12.3667±0.0333e
FRCUNCP_08	3.99±0.0058d	0,8367±0,0033c	16.5333±0.0333d
FRCUNCP_09	4.16±0.0058e	0.9900±0.0033f	16.9667±0.0333d
FRCUNCP_10	3.68±0.0173a	0.8100±0.0000d	14.6667±0.6667a
FRCUNCP_11	3.77±0.0000b	0.7833±0.0033c	13.7333±0.0333b
FRCUNCP_12	3.62±0.0058a	1.1133±0.0033g	17.7000±0.0000d
FRCUNCP_13	3.96±0.0058d	0.7867±0.0033c	13.6000±0.0000b
FRCUNCP_14	3.83±0.0058b	0.8100±0.0000d	13.7000±0.0000b

Different letters indicate statistically significant differences ($p< 0.05$).

Titratable acidity

Table 2 shows that the acidity of the pulps varied between 0.75 % (FRCUNCP_05) and 1.11 % (FRCUNCP_12), evidencing a remarkable diversity between genotypes. This variability may be related to the maturity state of the fruit (Arrazola-Paternina *et al.*, 2013). The high level of acidity in FRCUNCP_12 is favorable for producing juices and preserves, as it contributes to microbiological stability. In contrast, the low level of acidity in FRCUNCP_05 makes it more suitable for fresh consumption. These differences reflect the potential for differential use of genotypes for both industry and the fresh market (Villarreal-Fuentes *et al*., 2020).

The acidity values obtained (0.75 -1.11 %) are consistent with the variability reported by Jiménez-Zurita *et al*. (2017) in Mexico (0.87 %) and Onimawo (2002) in Nigeria (up to 3.43 %). This diversity confirms the influence of genotype, maturity state, and agroecological conditions on this parameter, as also highlighted by Villarreal-Fuentes *et. al*. (2020), who found wide variations in acidity between local genotypes in Chiapas, Mexico.

Total soluble solids (°Brix)

Table 2 shows that the °Brix degrees of the evaluated pulps vary between 12.37 (FRCUNCP_07) and 17.7 (FRCUNCP_12), values that are within or very close to those reported by Ojeda de Rodríguez *et. al*. (2007). These differences may be associated with the maturity state of the fruit (Arrazola-Paternina *et al*., 2013). Fruits with high °Brix degrees are suitable for fresh consumption or in juices, while those with lower sweetness could be used for products for special diets (Durán Agüero *et al*., 2012).

The results obtained with values between 12.37 and 17.70 °Brix are relevant for the food industry, since °Brix degrees are directly related to the perception of fruit sweetness (Jiménez-Zurita *et al*., 2016). Abdul Wahab *et al*. (2018) also found significant variations in the °Brix degrees of soursop, which is crucial for its commercialization and processing.

Mineral content

Table 3 shows the mineral content (phosphorus, magnesium, and calcium) determined in the pulp of soursop genotypes selected in San Ramón, Junín.

Table 3. Phosphorus, magnesium, and calcium content in the pulp of soursop genotypes selected in San Ramón, Junín.

Genotypes	Minerals	Mean (mg.100 g^{-1})
FRCUNCP_08		23.135± 0.003^{a}
FRCUNCP_09	Phosphorus	31.437±0.033^{c}
FRCUNCP_12		30.142±0.008^{c}
FRCUNCP_08		21.604±0.004^{c}
FRCUNCP_09	Magnesium	9.893±0.003^{b}
FRCUNCP_12		8.442± 0.003^{a}
FRCUNCP_08		4.112±0.003^{a}
FRCUNCP_09	Calcium	6.200±0.010^{c}
FRCUNCP_12		4.983±0.007^{b}

Different letters indicate statistically significant differences ($p< 0.05$).

The determination of the mineral content was carried out only in the plants whose pulps presented the highest °Brix degrees and pH close to 4, as they were considered of better quality. Regarding phosphorus content, genotype FRCUNCP_09 had the highest content, followed by FRCUNCP_12, while FRCUNCP_08 showed the lowest value. This variability could be influenced by factors such as soil type, agronomic management, and nutrient availability (Kome *et al*., 2024). Phosphorus is an essential mineral for the formation of bones and teeth, as well as for energy storage. The observed values are close to the reference value of 43 mg.100g^{-1} reported by the National Ministry of Health-National Institute of Health (MINSA, 2009).

Regarding magnesium, FRCUNCP_08 had the highest concentration, with values like those reported by León Méndez *et al*. (2016) in soursops grown in Colombia (20 mg.100g^{-1}). It is followed by FRCUNCP_09 and FRCUNCP_12, with significantly lower concentrations. This difference suggests an important variability in the capacity for magnesium accumulation between genotypes, which is relevant given that this mineral participates in essential biological functions such as enzyme regulation and neuromuscular activity.

Regarding calcium content, genotype FRCUNCP_09 showed the highest content (6.20 mg.100g^{-1}), followed by FRCUNCP_12 and FRCUNCP_08. However, these values are below the mean of 13.99 mg.100g^{-1} reported by Fernández *et al.* (2007) for fruits from the Western region of Venezuela. Such differences could be due to genetic variations, soil and climatic conditions, and cultivation practices.

The variability in the content of phosphorus, magnesium, and calcium in the pulp, observed among the soursop genotypes evaluated, can be exploited for the selection of materials with specific nutritional profiles, which is useful in genetic improvement programs or specialized production. Likewise, factors such as fertilization, available organic matter, soil type, and climatic conditions have a significant influence on the absorption and accumulation of these essential nutrients.

The statistical results indicate significant differences between the genotypes in the content of each mineral. In particular, the mean phosphorus content in FRCUNCP_09 was significantly higher than in FRCUNCP_08, while for magnesium, FRCUNCP_08 surpassed the others. The FRCUNCP_09 genotype has the highest calcium content, which is beneficial, since calcium is essential for bone health and muscle function. These results are important for assessing the potential use of these pulps in functional diets or value-added products, in which the concentration of minerals can be a determining criterion for the selection of plant material.

Conclusions

The present study identified significant variability in the physicochemical characteristics of fruits of soursop genotypes (*Annona muricata* L.) from sexually propagated plants cultivated in San Ramón, Junín. The FRCUNCP_08, FRCUNCP_09, and FRCUNCP_12 genotypes stood out for their higher yield, pulp quality, and nutritional content, especially in minerals such as phosphorus, magnesium, and calcium. These results suggest that the mentioned genotypes are promising for genetic improvement programs and development of nutraceutical products, contributing to the strengthening of the soursop value chain. The selection and propagation of these materials can improve the competitiveness of the crop in national and international markets, promoting its use as a key phytogenetic resource for the food industry.

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