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Physicochemical characterization of andean papaya in southern Peru

ARTÍCULO ORIGINAL

Caracterización fisicoquímica de papaya andina en el sur de Perú

Caracterização físico-química da papaia andina no sul do Peru

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ABSTRACT

The Andean papaya (*Carica pubescens*) is an underexplored fruit with significant agro-industrial potential due to its unique characteristics and non-seasonal production. This study aimed to characterize Andean papaya produced by the "Asociación de Productores de Papaya Andina Orgánica de la Provincia de Sandia" (ASPPAO) in Peru. Random samples were analyzed one-day post-harvest to assess weight distribution, physicochemical properties, and color. Results indicated an average fruit weight of 192.26 ± 19.86 g, with a distribution of 56.62% mesocarp, 26.73% endocarp (including 5.61% seeds and 21.12% mucilage), and 16.65% peel. The endocarp, which is the most used part for processing, had a favorable proportion and high value compared to other fruits. The fruit had an average width of 93.18 ± 9.36 mm, height of 69.61 ± 9.55 mm, and volume of 220.50 ± 35.39 cm³, showing variation due to size differences between fruits. Each fruit contained an average of 150.10 ± 19.93 seeds, with a texture of 9.52 ± 2.28 kg/cm², a mesocarp thickness of 11.57 ± 1.30 mm, and a pH of 4.75 ± 0.71. The color analysis revealed that the peel was yellow, the pulp slightly yellow, the mucilage values close to white, and the seeds light brown. The fruit had a low total solids content and titratable acidity expressed in vitamin C with a maturity index of 14.37 ± 3.29. Additionally, chemical differences were observed between the pulp and mucilage, with the latter having higher values of total solids and titratable acidity and slightly more acidic pH values. Further studies are necessary to investigate the chemical content of this product and its potential health effects.

Key words: Andean papaya; *Carica pubescens*; Maturity index; Sandia; ASPPAO

RESUMEN

La papaya andina (*Carica pubescens*) es una fruta poco explorada con un importante potencial agroindustrial debido a sus características únicas y a su producción no estacional. Este estudio tuvo como objetivo caracterizar la papaya andina producida por la «Asociación de Productores de Papaya Andina Orgánica de la Provincia de Sandia» (ASPPAO) en Perú. Se analizaron muestras aleatorias un día después de la cosecha para evaluar la distribución del peso, las propiedades fisicoquímicas y el color. Los resultados indicaron un peso promedio del fruto de 192,26 ± 19,86 g, con una distribución de 56,62% de mesocarpo, 26,73% de endocarpo (incluyendo 5,61% de semillas y 21,12% de mucílago) y 16,65% de cáscara. El endocarpio, que es la parte más utilizada para la transformación, tenía una proporción favorable y un valor elevado en comparación con otras frutas. Los frutos tenían una anchura media de 93,18 ± 9,36 mm, una altura de 69,61 ± 9,55 mm y un volumen de 220,50 ± 35,39 cm³, mostrando variaciones debidas a las diferencias de tamaño entre los frutos. Cada fruto contenía una media de 150,10 ± 19,93 semillas, con una textura de 9,52 ± 2,28 kg/cm², un grosor del mesocarpio de 11,57 ± 1,30 mm, y un pH de 4,75 ± 0,71. El análisis del color reveló que la cáscara era amarilla, la pulpa ligeramente amarilla, los valores del mucílago cercanos al blanco y las semillas marrón claro. El fruto tenía un bajo contenido en sólidos totales y acidez titulable expresada en vitamina C, con un índice de madurez de 14,37 ± 3,29. Además, se observaron diferencias químicas entre la pulpa y el mucílago, presentando este último valor más alto de sólidos totales y acidez titulable y valores de pH ligeramente más ácidos. Son necesarios más estudios para investigar el contenido químico de este producto y sus posibles efectos sobre la salud.

Palabras clave: Papaya andina; *Carica pubescens*; Índice de madurez; Sandia; ASPPAO

RESUMO

O mamão andino (*Carica pubescens*) é uma fruta pouco explorada com grande potencial agroindustrial devido às suas características únicas e à produção não sazonal. Este estudo teve como objetivo caracterizar o mamão andino produzido pela "Asociación de Productores de Papaya Andina Orgánica de la Provincia de Sandia" (ASPPAO) no Peru. Amostras aleatórias foram analisadas um dia após a colheita para avaliar a distribuição do peso, as propriedades físico-químicas e a cor. Os resultados indicaram um peso médio do fruto de 192,26 ± 19,86 g, com uma distribuição de 56,62% de mesocarpo, 26,73% de endocarpo (incluindo 5,61% de sementes e 21,12% de mucilagem) e 16,65% de casca. O endocarpo, que é a parte mais usada para processamento, teve uma proporção favorável e alto valor em comparação com outras frutas. Os frutos tinham uma largura média de 93,18 ± 9,36 mm, altura de 69,61 ± 9,55 mm e volume de 220,50 ± 35,39 cm³, mostrando variação devido às diferenças de tamanho entre os frutos. Cada fruto continha uma média de 150,10 ± 19,93 sementes, com textura de 9,52 ± 2,28 kg/cm², espessura do mesocarpo de 11,57 ± 1,30 mm e pH de 4,75 ± 0,71. A análise de cor revelou que a casca era amarela, a polpa ligeiramente amarela, os valores de mucilagem próximos ao branco e as sementes marrom-claras. O fruto tinha baixo teor de sólidos totais e acidez titulável expressa em vitamina C, com um índice de maturidade de 14,37 ± 3,29. Além disso, foram observadas diferenças químicas entre a polpa e a mucilagem, com a última apresentando valores mais altos de sólidos totais e acidez titulável e valores de pH ligeiramente mais ácidos. São necessários mais estudos para investigar o conteúdo químico desse produto e seus possíveis efeitos à saúde.

Palavras-chave: Papaia andina; *Carica pubescens*; Índice de maturidade; Sandia; ASPPAO

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INTRODUCTION

The Andean papaya (*Carica pubescens*), known locally as papayuela, mountain papaya, or height papaya, is a fruit native to the Andean region, specifically in the provinces of Carabaya and Sandia in the Puno region of Peru. It thrives at elevations ranging from 1600 to 2800 meters above sea level. This fruit is distinguished by its aromatic qualities and has substantial agro-industrial potential due to its diverse applications and non-seasonal production (1).

The Andean papaya is rich in bioactive compounds, including phenolic compounds, carotenoids like β-carotene, and vitamin C. These components are known for their antioxidant properties, which can contribute to reducing oxidative stress and mitigating the risk of chronic diseases, such as cancer (2,3). The fruit's medicinal benefits have been documented in various studies, highlighting its potential as a health-promoting food (4). Additionally, changing consumer preferences towards natural and organic products have increased the demand for fruits with such health benefits (5,6).

Physicochemical characterization is essential for understanding the properties and potential uses of a product. This process involves detailed analysis, which can be either basic or comprehensive, depending on the study's objectives and available resources (7,8). The primary goal of characterization is to generate critical data for the effective utilization and processing of the product (9,10). This is particularly important for underexplored products with significant potential, as detailed characterization can facilitate their integration into various markets and applications (11-14).

Despite its potential, the Andean papaya remains relatively unknown and underutilized, with limited research and dissemination of its attributes (1,15). Existing studies on this fruit are sparse and dispersed, contributing to its marginal status in the agro-industrial sector. Therefore, there is a pressing need to expand knowledge about the Andean papaya, particularly regarding its physicochemical properties and transformation possibilities. This study aims to address this gap by providing a thorough physicochemical characterization of Andean papaya (*Carica pubescens*), which is expected to support further research, development, and commercialization efforts.

MATERIALS AND METHODS

Place of Execution

The research was conducted in the engineering, postharvest, process, and pilot plant laboratories of the Department of Agroindustrial Engineering at the Universidad Nacional del Altiplano in Peru (latitude: -15.823073, longitude: -70.018815) from September to November 2021.

Biological Material

The biological material consisted of Andean papaya fruits harvested from crops located at

latitude: 14°20'26'', longitude: 69°28'08''. Fruits were collected at the mature stage from the Asociación de Productores de Papaya Andina Orgánica de la Provincia de Sandia (ASPPAO). One hundred samples were randomly selected and harvested the day prior to the analysis, with a relative humidity of 93.81%.

Characterization

The weight distribution was characterized using an analytical balance (OHAUS model PA3102, USA). Measurements included fruit weight (FW), epicarp weight or peel (EPW), mesocarp weight (MW), and endocarp weight (ENW). The endocarp was further divided into seed weight (SW) and mucilage weight (MUW). The percentage of each component relative to the total fruit weight was calculated.

Fruit length (L) and width (A) were measured using a digital Vernier (Fig. 1A), as well as mesocarp thickness (MT). Seed number (SN) was counted manually (Fig. 1B). Volume (V) was determined using the water displacement method in a graduated cylinder. Texture (T) was measured with a portable double range fruit penetrometer (NUMAK model DFZ-3, Germany) with a needle thickness of 2.4 mm. Color was assessed using a colorimeter (BLUE model HP213, China) according to the CIE Lab system as described by Nuñez (16) and Araya-Morice et al. (17).

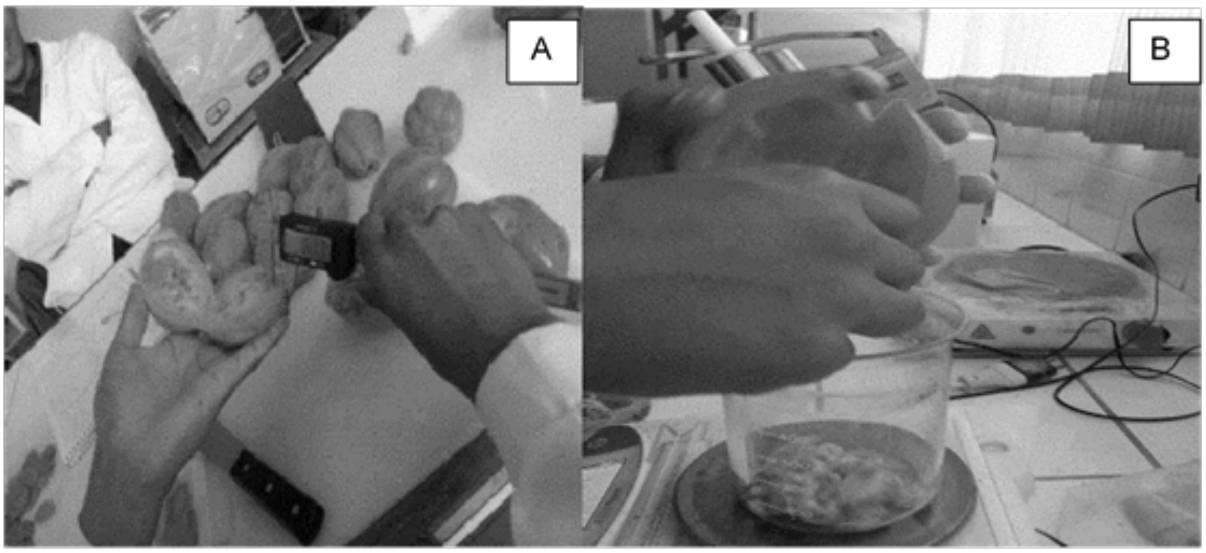

***Figura* 1 A).** Characterization of weight distribution and B) seed number Experimental design.

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Chemical characterization was performed at 20.7°C with a digital refractometer (ATC model HI96801, China) to measure total solids (TS) and a digital pH meter (HANNA model HI98128, Romania). Titratable acidity (TA) was determined following the traditional method outlined by Crosa et al. (18). Measurements were conducted for pulp (PU) and mucilage (M). The maturity index (MI) was calculated as the ratio of total soluble solids (TSS) to titratable acidity (TA), following the method described by Brunini et al. (19).

Experimental Design

A completely randomized design was used, and descriptive statistics were calculated with RStudio Desktop 2022 software, version R 3.3.0+, as recommended by Simirgiotis et al. (20).

RESULTS AND DISCUSSION

Weight Distribution

The results are shown in Table 1, indicating variability in the weight of the fruits, with a minimum value of 160.39 g and a maximum value of 215.20 g. The mesocarp had the highest weight, followed by the endocarp and epicarp, with percentages representing 56.62% for mesocarp compared to 26.73% and 16.65%, respectively. Additionally, there was a high mucilage content of 21.12% relative to the total weight, which was subjected to a pectin presence test. The test was positive, indicating a medium-high pectin content in the mucilage, unlike traditional papaya (*Carica papaya*), as indicated by Ríos (21).

Tabla 1. Andean papaya weight distribution.

N°	FW(g)	EPW(g)	MW(g)	ENW(g)	SW(g)	MUW(g)	%EPW	%MW	%ENW	%SW	%MUW
x̄	191.26	31.54	108.74	50.98	10.65	40.33	16.65	56.62	26.73	5.61	21.12
SE	19.86	4.41	16.90	6.73	2.91	6.25	2.78	3.99	3.01	1.62	2.63

x̄: average, SE: standard error.

The percentage of seeds at 5.61% was higher than that of traditional papaya (*Carica papaya*), as indicated by Ríos (21), and higher than for cocoa, as indicated by Álvarez (22). This is due to the lower weight of these other fruits and the limited empty space in the mesocarp.

The results regarding peel yield were 83.35%, while Cornejo (23) obtained 85.68%. The difference arises because Cornejo (23) used chemical peeling, which provides a better final presentation of the product. This author also determined TA and pH values of 0.34 and 4.20, respectively. Concha (24) determined TA 0.37%, pH 4.20, TSS 6.00, and humidity 90.49%. In this study, values of TA 0.392 ± 0.08, TSS 5.41 ± 0.51, and pH 4.75 ± 0.71 were obtained, indicating that Andean papaya from Sandia has more vitamin C compared to the results of Cornejo (23), who used Andean papaya from Arequipa, and Concha (24), who used Andean papaya from Venezuela. The higher TA

and pH values are due to the organic raw material cultivated at high altitude.

Regarding the mesocarp percentage, 56.62% ± 3.99% was obtained, a higher value than that reported by de Jesús Guerrero et al. (25) for traditional papaya (50%), due to the size difference. Rehm & Espig (26) used the CIE Lab color system to determine color in different fruits, including Andean papaya, obtaining similar values to those in this study. Regarding the epicarp, pulp color, and mucilage, no background information was found. It would also be important to characterize these wastes, as recommended by Neyra-Vásquez et al. (27).

Physical Characteristics

The results are detailed in Table 2, the characteristic with the highest standard deviation (SE) is volume, due to the variety of sizes of the fruit, with an average volume of 220.5 ± 35.39 cm^3. The average height and width were 93.18 ± 9.36 mm and 69.61 ± 9.55 mm, respectively. The texture of Andean papaya is firmer than that of traditional papaya, with an average resistance to penetration of 9.52 ± 2.28 kg/cm^2 compared to 7.68 kg/cm^2 found by Ríos (21). On average, there were 150 seeds per fruit. The mesocarp thickness was, on average, 11.57 ± 1.30 mm.

Tabla 2. Andean papaya physical characteristics.

N°	L(mm)	A(mm)	V(cm^3)	SN	T(kg/cm^2)	MT(mm)
x̄	93.18	69.61	220.50	150.10	9.52	11.57
SE	9.36	9.55	35.39	19.93	2.28	1.30

x̄: average, SE: standard error.

The results indicate a significant variability in the physical characteristics of Andean papaya. The firmness of the fruit suggests that it may have better resistance to mechanical damage during handling and transport compared to traditional papaya. The average seed number and mesocarp thickness also provide valuable information for processing and industrial applications.

In comparison with traditional papaya, the higher firmness and mesocarp thickness might contribute to its suitability for different agro-industrial processes. These physical attributes could enhance the quality and shelf life of processed products derived from Andean papaya.

Chemical Characteristics

The results are shown in Table 3. The total soluble solids (TS) content of the pulp was lower than that of the mucilage: 5.41 ± 0.51 °Brix versus 9.36 ± 0.86 °Brix, and the opposite in pH value: 4.75 ± 0.71 versus 4.39 ± 0.10. For titratable acidity (TA), the content was higher in the mucilage: 0.622 ± 0.07% versus 0.392 ± 0.08% in the pulp. The TA value was higher than that of traditional papaya (C. papaya) as indicated by Gaona & Ramírez (1) and Ríos (21), and the average maturity index (MI) was 14.37.3

Tabla 3. Andean papaya chemical characteristics.

N°	TS (°Brix) PU	pH PU	%TA PU	MI	TS (°Brix) M	pH M	%TA M
x̄	5.41	4.75	0.392	14.37	9.36	4.39	0.622
SE	0.51	0.71	0.08	3.29	0.86	0.10	0.07

x̄: average, SE: standard error.

The higher TS content in the mucilage compared to the pulp indicates that the mucilage has a higher concentration of soluble sugars. This finding aligns with the higher TA value in the mucilage, suggesting that the mucilage contributes significantly to the fruit's acidity. The pH values indicate that both the pulp and mucilage are slightly acidic, with the pulp being slightly more acidic than the mucilage.

The maturity index (MI) of 14.37 is an important indicator of the fruit's ripeness and quality, providing a balance between sweetness and acidity. This value is comparable to other fruits used in agro-industrial processes, suggesting that Andean papaya has suitable characteristics for various applications.

In comparison with traditional papaya, the higher TA and pH values in Andean papaya could be attributed to the organic cultivation practices and the high-altitude growing conditions, which are known to affect the chemical composition of fruits.

Color Characteristics

The results are detailed in Table 4 using the CIE Lab color system. It was noted that the peel had a higher lightness value (L) of 58.03 compared to 57.37 for the pulp. The *a and *b values suggested that the peel had a yellow color similar to the pulp but with less intensity. The mucilage was white with a high value of L (60.28 ± 5.99), while the pulp was light brown with values of *a: 7.30, 3.32, 3.48, 13.08 and *b: 49.84, 22.98, 7.82, 17.49, respectively.

Tabla 4. Andean papaya color characteristics.

	L	a*	b*		L	a*	b*
Peel	x̄	58.03	7.30	49.84	SE	2.15	2.85
Pulp	x̄	57.37	3.32	22.98	SE	1.66	1.66
Mucilage	x̄	60.28	3.48	7.82	SE	5.99	2.99
Seed	x̄	31.92	13.08	17.49	SE	4.46	3.63

x̄: average, SE: standard deviation.

The lightness value (L) indicates how light or dark a color appears, with higher values representing lighter colors. The Andean papaya peel had a slightly higher lightness value than the pulp, indicating a marginally lighter appearance. The mucilage had the highest lightness value, making it the lightest part of the fruit, while the seeds were significantly darker.

The *a values represent the red-green axis, where positive values indicate red tones and negative values indicate green tones. The peel had higher *a values compared to the pulp, suggesting a more intense red color. The *b values represent the yellow-blue axis, where positive values indicate yellow tones and negative values indicate blue tones. The peel had higher *b values than the pulp, indicating a more intense yellow color Table 5.

Tabla 5. Andean papaya color range.

	Min	Mean	Max
Peel			
Pulp			
Mucilage			
Seed			

These color characteristics are essential for the visual appeal of the fruit and its derived products. The differences in lightness and color intensity between the different parts of the fruit can be crucial for consumer acceptance and marketability. Additionally, the high lightness value of the mucilage could be beneficial for processing into products where a light color is desired.

According to Rehm & Espig (26), the CIE Lab color system is a standardized method for determining color in different fruits, including Andean papaya, obtaining values similar to those of this study. The information about the color characteristics of the epicarp, pulp, and mucilage for Andean papaya was not found in other sources; therefore, it would be important to characterize these wastes as recommended by Neyra-Vásquez et al. (27).

CONCLUSIONS

The physicochemical characterization of Andean papaya (Carica pubescens) provided valuable insights into its potential uses and applications. The average weight of the Andean papaya was 192.26 ± 19.86 g, with the weight distribution being 56.62% mesocarp, 26.73% endocarp, 5.61% seeds, 21.12% mucilage, and 16.65% peel. The high proportion of mesocarp

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and endocarp suggests significant potential for transformation and utilization, particularly in agro-industrial processes.

The physical characteristics of the fruit showed an average width of 93.18 ± 9.36 mm, height of 69.61 ± 9.55 mm, and volume of 220.50 ± 35.39 cm^3. The variability in these measurements indicates diverse fruit sizes, which should be considered in processing and standardization. The average number of seeds per fruit was 150.10 ± 19.93, with a texture of 9.52 ± 2.28 kg/cm^2, demonstrating greater firmness compared to fruits from other regions. The mesocarp thickness averaged 11.57 ± 1.30 mm, providing a substantial portion for potential processing.

In terms of color, the peel was yellow, the pulp was slightly yellow, the mucilage was close to white, and the seeds were light brown. The Andean papaya exhibited an acidity level with a pH of 4.75 ± 0.71, and a low total solids content and titratable acidity, with a maturity index (MI) of 14.37 ± 3.29. The mucilage had higher total solids (TS) and titratable acidity (TA) compared to the pulp, along with a slightly more acidic pH.

The findings highlight the need for further research into the chemical content and health benefits of Andean papaya, particularly focusing on its bioactive compounds and their potential effects. This characterization establishes a foundation for developing processing techniques and value-added products derived from this promising fruit.

CONFLICT OF INTERESTS. The authors declare that there is no conflict of interest for the publication of this scientific article.

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