



Memories of the Agricultural and Livestock Area of the VI CCIUTM, Ecuador

Physico-Chemical Characterization of Maqueño Banana (*Mussa acuminata*) Fruits

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Abstract | The banana (*Mussa acuminata*) is a fruit native to Asia and has been a staple food for centuries due to its high nutritional value and versatility. The Maqueño banana “Red Dacca” is a unique variety with a reddish-purple skin, smaller size, and greater nutrient density compared to the conventional yellow banana. Its flavor, often likened to fresh raspberries, makes it a promising alternative for both local consumption and export. Despite its potential, limited scientific data on Maqueño bananas produced in Ecuador has prompted this study, which aims to characterize their physical and chemical properties. This research was conducted in El Empalme and La Maná, two Ecuadorian towns, to evaluate how geographical location and post-harvest time influence fruit quality. A Completely Random Design (DCA) with a factorial arrangement (A x B) was applied, involving 6 treatments and 3 repetitions. Factor A represented geographical location, while Factor B corresponded to optimal consumption time. Significant differences were observed among the parameters analyzed ($p \leq 0.05$). Physical parameters included firmness, length, and pulp/peel ratio, while chemical parameters comprised acidity, pH, humidity, ash, and Brix degrees. Proximal analysis quantified fat, protein, fiber, and polyphenols. Notably, samples from La Maná exhibited slower firmness loss, attributed to higher fiber content, total solids, and protein levels. These findings provide a comprehensive understanding of Maqueño bananas, underscoring their suitability for nutritional and functional food applications and their potential role in sustainable agricultural practices.

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Introduction

Bananas (*Musa acuminata*) are among the most commercially significant agricultural products

for Ecuador, contributing 2% to the Gross Domestic Product (GDP) and approximately 35% to the agricultural GDP. With an estimated crop area of 160,000 hectares and around 4,500 producers ranging

from small to large-scale operations, bananas represent the cornerstone of Ecuador's agricultural economy. According to statistics from the National Institute of Statistics and Censuses (INEC) (Quezada *et al.*, 2021), the nationwide cultivated area is distributed as follows: approximately 27.48% in Los Ríos province, 29.76% in Guayas province, 20.43% in El Oro province, and 22.32% across the remaining provinces of Ecuador, respectively. Beyond its economic impact, banana production generates employment and provides a nutritious, vitamin-rich food source that supports consumer health (Veliz *et al.*, 2022).

In 2015, Ecuador exported six million tons of bananas, generating \$2.706 billion in revenue. Major markets included Russia, the United States, Germany, and Turkey. Comparatively, exports in 2000 amounted to four million tons, reflecting a 53% growth in export volume over 15 years. Yield also improved significantly, increasing from 1,001 boxes per hectare per year in 2013 to 1,618 boxes per hectare per year in 2015, largely due to enhanced crop management practices (Quiloango *et al.*, 2022).

The Maqueño banana, also known as the purple banana, represents a promising alternative for commercial exploitation, particularly in humid regions where the Cavendish variety is more susceptible to black Sigatoka disease. This variety is distinguished by its reddish-purple skin, smaller and thicker fruits, and an internal coloration ranging from yellow to pale pink. Its flavor is sweet, with some varieties featuring subtle raspberry undertones. This banana is known by various names across the world: Red Banana, Taffeta, Purple Guinea, or Pink Banana in the Americas; Pink Banana, Cuban Banane, or Claret Colored Banana in Europe; and Red Dhaka or Red Banana in English-speaking regions (Tuárez *et al.*, 2023).

Despite its potential, limited scientific information is available on the Maqueño banana. This research aims to evaluate its physical and chemical characteristics during ripening, harvest, and post-harvest stages. Laboratory analyses were conducted to establish consistent quality parameters for optimal consumption and export, contributing to the fruit's broader commercial viability.

Materials and Methods

Localization

This research was conducted in the Bromatology

Laboratory, located on the "La María" campus of the State Technical University of Quevedo, at Km 7 1/2 of the Quevedo–El Empalme road. The laboratory is situated at the geographical coordinates of 01° 06' South latitude and 79° 29' West longitude. Banana samples were obtained from local markets in the cities of El Empalme and La Maná. The physical-chemical analyses were performed in the Bromatology Laboratory, while the nutritional analyses were conducted at the INIAP "Santa Catalina Experimental Station." The meteorological conditions of the research site were recorded (Table 1), along with details of the sample collection locations, specifically the cities of El Empalme (Table 2) and La Maná (Table 3).

Table 1: *Weather conditions of the research site.*

Aspect	Unit	Average value
Altitude	M.s.n.m.	480
Temperature	°C	24
Relative humidity	%	84
Annual rainfall	mm	2178
Heliofanía	Hours/light/year	845,80
Ecological zone		Tropical semi-humid forest

Source: Veliz and Chevez (2020)

Table 2: *Weather conditions of El Empalme canton.*

Aspect	Unit	Average value
Altitude	M.s.n.m.	27
Temperature	°C	24 a 25
Relative humidity	%	84,4
Annual rainfall	mm	1500 a 2300
Ecological zone		Megathermal tropical zone

Source: Veliz and Chevez (2020)

Table 3: *Weather conditions of La Maná canton.*

Aspect	Unit	Average value
Altitude	M.s.n.m.	215
Temperature	°C	24 a 25
Relative humidity	%	90
Annual rainfall	mm	4500
Heliofanía	Hours/light/year	718,9

Source: Veliz and Chevez (2020)

Research design

For the present research, a Completely Random Design (DCA) of type A x B was applied, with 6 treatments and 3 replications. To determine

differences between the means of treatments, the Tukey test ($p \leq 0.05$) will be used.

Outline of andeva

Study factors: Table 5 details the study factors involved in the research. As can be seen, factor A corresponds to the geographical location from which the samples were obtained, and factor B to the time elapsed since harvest. Additionally, Table 6 presents the research data processing.

Data processing

Mathematical model: In Table 4, the sources of variation are shown, and the following mathematical model will be applied:

$$Y_{ijk} = \mu + \text{Factor } a + \text{Factor } b + E_{ij}$$

Where: Y_{ijk} = total observations under study; μ = effect of the overall mean; Factor a = geographic location; Factor b = optimal consumption time; E_{ij} = error experimental.

Table 4: Andeva scheme to be used in research.

FV		Degrees of freedom
Treatment	(axb)-1	5
Factor A	(a-1)	1
Factor B	(b-1)	2
Interaction	(a-1) (b-1)	2
Error experimental	(axb) (r-1)	12
Total	(axbxn) (-1)	17

Source: Véliz and Chevez (2020)

Table 5: Study factors to be applied.

Code	Factors	Levels
A	Geographical location	The Manna A1
		The Junction A2
B	Optimal consumption time	1 day post-harvest B1
		5 days post-harvest B2
		10 days post-harvest B3

Source: Véliz and Chevez (2020)

Research instrument

In the following investigation, the following physical-chemical and nutritional analyzes were performed.

Physical variables

Firmness test: The firmness of the samples was determined from a unidirectional compression test

using a cylindrical stainless-steel shaft with a diameter of 2 mm, at a deformation rate of 2 mm/s and a strain distance of 20 mm for 10 days, the samples were evaluated for each day and each sample was evaluated at a distance corresponding to 25, 50 and 75 % of the length of the external curvature.

Longitude

Length in centimeters, of the fruit per unit for which a tape measure was used and was done as follows: It was determined by measuring the outer curvature of the individual finger with a tape from the distal end to the proximal end, where the pulp is considered to end.

Pulp/shell ratio

The pulp and shell are separated, weighed individually, and expressed as a pulp/shell ratio (i.e. the weight of the pulp divided by the weight of the shell).

Chemical variables

Acidity: The acidity analysis was conducted in the Bromatology Laboratory of the Faculty of Animal Sciences at the State Technical University of Quevedo. The procedure followed the AOAC 942.15/90 standard. To determine acidity, 20 g of the sample were homogenized and titrated with a standard sodium hydroxide (NaOH) solution, using phenolphthalein as an indicator. The results were expressed as a percentage of malic acid, which is the predominant organic acid in bananas. The precision of this method ensures reliable quantification of titratable acidity levels.

pH: The potentiometric method is established to determine the concentration of hydrogen ion (pH) in food. It was carried out in the Laboratory of Chemistry and Biochemistry of the Faculty of Livestock Sciences of the State Technical University of Quevedo. The procedure was in accordance with NTE INEN 038.

Humidity: The principle of the method is drying in an oven, using the stove technique at atmospheric pressure (105 °C) followed by standardised cooling conditions after drying in the oven. The analysis to determine humidity was performed in the Bromatology Laboratory of the Faculty of Livestock Sciences of the State Technical University of Quevedo. The procedure was in accordance with NTE INEN-ISO 1573.

Ash content: The determination of ash content was performed in accordance with the NTE INEN 520 standard. Fifty grams of each sample were weighed and incinerated in a muffle furnace at a temperature of 550°C until a constant weight was achieved. This method involves the complete combustion of organic materials, leaving only the inorganic mineral content as residue. The final ash weight was recorded and expressed as a percentage of the sample's dry weight. This technique ensures accurate determination of the sample's mineral content.

Degrees brix

It was carried out in the Laboratory of Chemistry and Biochemistry of the Faculty of Livestock Sciences of the State Technical University of Quevedo. The procedure was in accordance with laboratory regulations.

Table 6: Processing of research data.

Treatment	Code	Detail
T1	A1b1	Manna + 1 Days of Maturation
T2	A1b2	The Splice + 1 Days of Maturation
T3	A2b1	Manna + 5 Days of Maturation
T4	2ab2	The Splice + 5 Days of Maturation
T5	A3b1	Manna + 10 Days of Maturation
T6	A3b2	The Junction + 10 Days of Maturation

Source: Véliz and Chevez (2020)

Nutritional variable

Proximal analysis: Proximal analysis determines moisture, fat, fiber, ash, soluble carbohydrates, and protein percentages in food. It requires proper sample collection, treatment, and analytical methods, with results analyzed statistically and compared to regulations to ensure consumer validity.

Results and Discussion

Results physical analysis of bananas

Table 7 details the results of the physical analyses carried out in the physico-chemical characterization of the banana "Red Dhaka" (*Mussa acuminata*); were: Firmness measures resistance to physical damage caused by mechanical means during collection, handling and transport; It depends on the time and method of collection and the storage temperature (Chen and Linus, 2013).

The finger length variable was higher in samples from the geographic location of La Maná (T1, T2 and T3) (Ramirez *et al.*, 2011), indicate that for different banana varieties the largest amount of data was between 16 and 20cm (Gros Michel); and between 17 and 20cm (Congo clone).

Table 7: Results of physical analysis in the physical-chemical characterization of the banana maqueño "Red Dhaka" (*Mussa acuminata*).

Treatment	Firmness (kgf)	Length (cm)	P/c ratio (%)
T1	5.664	19.00	62.720
T2	4.247	18.50	62.220
T3	3.355	17.00	61.830
T4	6.703	18.50	62.300
T5	1.257	17.40	62.280
T6	0.975	16.90	61.140

Source: Véliz and Chevez (2020)

Regarding the pulp-shell ratio, during the 10 days after harvest there was no decrease in this variable, highlighting that the loss of firmness in the pulp during maturation varies according to the crop and type of banana. Smith argues that firmness is often related to maturation; This implies that, as maturation progresses, the firmness of the pulp decreases (Vásquez *et al.*, 2024).

Reduced firmness or softening during maturation has been associated with three processes. The first is the breakdown of starch to form sugar. The second process is the degradation of the cell walls or the reduction of the cohesion of the middle lamina, due to the solubilization of peptic substances (Paniagua *et al.*, 2014).

Results chemical analysis of bananas

Table 8 details the results of the chemical analyses carried out in the physico-chemical characterization of the banana "Red Dhaka" (*Mussa acuminata*); were:

Acidity (%): According to Andeva, in the variable acidity in the chemical characterization of the banana maqueño "Red Dhaka" (*Mussa acuminata*) there is a significant difference; determining that according to Tukey's test ($p \leq 0.05$), T2 (Manna; day 5) presented the highest value with 0.54%, while T4 (El Empalme; day 1) obtained the lowest value of 0.22% (Image 1).

The results obtained are comparable to who in the

evaluation of the quality of [Ramirez et al. \(2011\)](#), *Gros michel* banana fruit of height obtained values of 0.36% to 0.50%. This indicates that when the ripening time increases, the malic acid content changes during the fruit ripening process.

Table 8: Results of acidity, pH, humidity, ash and °Brix of the physical-chemical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*).

Treatment	Acidity %	pH	Humidity %	Ashes %	°Brix
T1	0.28b	5.54from	71.13from	0.29a	5.53a
T2	0.54e	5.17from	74.03c	0.59b	16.40c
T3	0.32c	5.27from	76.63d	0.70c	22.53d
T4	0.22a	5.11a	70.83from	0.29a	5.87a
T5	0.48d	5.65b	72.23b	0.61b	13.37b
T6	0.28b	5.27from	70.13th	0.84d	18.13c
Average	0.35	5.34	72.50	0.55	13.64
C.V. (%)	4.57	4.82	1.20	7.98	7.99

Source: Véliz and Chevez (2020)

Acidity measured as titular acidity in the pulp tissues of most bananas shows large increases during ripening or as ripening progresses. Therefore, total titrator acidity could be used as a ripening index ([Racines et al., 2019](#)).

pH: According to Andeva, in the pH variable in the chemical characterization of the banana “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), T5 (El-Empalme; day 5) presented the highest value with 5.65, while T4 (El-Empalme; day 1) obtained the lowest value of 5.11 (Image 2).

The values of [Campuzano et al. \(2010\)](#), are equal to those of this work by obtaining values between 5 and 5.9 pH in the post-harvest behavior of Cavendish bananas. pH is a very important parameter in the production of food products, both as an indicator of hygienic conditions and for the control of transformation processes. Below 3.7 only fungi can develop. The key point is at pH 4.5. Generally, when fruits are harvested with the degree of ripe green maturity the pH of the pulp is high, but as ripening progresses, the pH drops. Thus, the pH of the pulp could be used as a ripening index ([Vásquez et al., 2024](#)).

Humidity: According to Andeva, in the humidity

variable in the physical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), T3 (Manna; day 10) presented the highest value with 76.63%, while the lowest value was T4 (El-Empalme; day 1) with 70.83% (image 3).

The humidity values are similar to those obtained by Casallas who in the physicochemical analysis of the common banana presented a value of 72.1%. The moisture content in a food is often a stability index of the product ([Casallas, 2010](#)).

It becomes a quality factor in the preservation of some products, as it affects the stability of different fruits and vegetables. Knowing the humidity of food allows to determine its centesimal composition, facilitate its preparation, prolong its conservation and, especially, prevent the product from being adulterated ([Claudia and Claudia, 2012](#)).

Ash: According to Andeva, in the variable ashes in the physical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), T6 (El-Empalme; day 10) presented the highest value of 0.84%, while T4 (El-Empalme; day 1) and T1 (La Maná; day 1) obtained 0.29%, being the lowest values (image 4).

[Martínez et al. \(2016\)](#) describes that, in the chemical composition of different varieties of banana, it presented higher values between 2.5% and 3.0% ashes; while Casallas obtained similar values of 0.09% ([Casallas, 2010](#)). The determination of ashes is referred to as the analysis of inorganic residues that remain after the ignition or complete oxidation of the organic matter of a food; it allows to detect possible metallic contaminations in food ([Márquez, 2014](#)). There are several factors that influence the amount of ash, representing the total content of minerals in food resulting in great importance to be part of the proximal analysis to determine the nutritional value, as well as to know the purity of the elements used in the preparation of the product thus helping to identify if the food has been adulterated or contaminated ([Vera et al., 2023](#)).

Total soluble solids (°Brix)

According to Andeva, in the variable °Brix in the chemical characterization of the banana maqueño

“Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), T (Manna; day 15) presented the highest value with 22.53, while T1 (Manna; day 1) obtained 5.53 being the lowest value (image 5).

These values are similar to those obtained by Ramírez *et al.* who obtained 17.84 to 19.10 °Brix. Brix measures the amount of soluble solids present in food expressed as a percentage of sucrose. Soluble solids are composed of sugars, acids, salts and other water-soluble compounds present in the juices of food cells. They are determined using a calibrated refractometer and at 20 °c. The importance of determining the content of Brix degrees is that the amount of these help to know the nutritional status of food and inhibits the growth of microorganisms in food attracting water in an osmosis process (Ramírez *et al.*, 2011).

Results proximal analysis

Table 9 details the results of the proximal analyses carried out in the physical-chemical characterization of the banana “Red Dhaka” (*Mussa acuminata*); were:

Table 9: Results of fat, protein and fiber of the physical-chemical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*).

Treatment	Fat %	Protein %	Fiber %	Polyphenols mg/g
T1	0.68	4.19	0.48	13.07
T2	0.55	4.53	0.33	12.74
T3	0.62	4.98	0.43	12.36
T4	0.55	4.16	0.23	20.97
T5	0.55	3.75	0.34	22.57
T6	0.62	3.67	0.40	20.47
Average	0.60	4.21	0.37	15.36
C.V. (%)	7.36	1.48	11.64	4.83

Source: Véliz and Chevez (2020)

Grease: According to Andeva, in the fat variable in the physical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), the highest value was T1 (Manna; day 1) presented the highest value with 0.68%, while T2 (Manna; day 5), T4 (El-Empalme; day 1) and T5 (El Empalme; day 5) presented 0.55% each (image 6).

These values are similar to those obtained by Casallas who presented values of 0.5%. Fat content is one of the five most important parameters for assessing food

quality. Fat content is also an important magnitude and is determined as crude fat based on Weende’s analysis process. In the food trade, the fat content is usually, together with other parameters, decisive for the price of the product. The so-called total fat content also includes fats and additional components that can be dissolved in the fat solvent, excluding free fat (Casallas, 2010).

Protein: According to Andeva, in the protein variable in the physical-chemical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), the highest value was T3 (La Maná; day 10) presented the highest value with 4.98%, while T6 (El-Empalme; day 5), obtained 3.75% being this the lowest value (Image 7).

Dortmon *et. To the.* in the chemical composition of ripe bananas presented values higher than 10.45%; while Casallas obtained values lower than 1.1%. Proteins are the materials that perform a greater number of functions in the cells of all living beings. On the one hand, they are part of the basic structure of tissues (muscles, tendons, skin, nails, etc.) And, on the other, they perform metabolic and regulatory functions (assimilation of nutrients, transport of oxygen and fat in the blood, inactivation of toxic or dangerous materials, etc.). It should be noted that after harvest, while a higher protein content could be related to a lower starch content (Casallas, 2010).

Fibre: According to Andeva, in the fiber variable in the chemical characterization of the banana maqueño “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), the highest value was T1 (Manna; day 1) presented the highest value with 0.48%, while T4 (El Empalme; day 1), obtained 0.23% being this the lowest value (Image 8).

Casallas recorded similar fiber values with 0.5% in fresh bananas and 1.2% in dehydrated bananas (Casallas, 2010).

Crude fiber analysis is based on sequential treatment with acids and alkalis under standardized conditions. With this method, the FD content is significantly undervalued since much of the hemicellulose and lignin, varying amounts of cellulose and all soluble fiber are dissolved. Crude fiber values have no relation

to the true FD value of human food. FD values are generally 3 to 5 times higher than crude fiber values, but a correction factor cannot be made because the ratio of crude fiber to FD varies depending on the chemical components. Crude fiber has little physiological significance in human nutrition and should not be used to inform the fiber content of foods (Timm *et al.*, 2023).

Polyphenols: According to Andeva, in the polyphenol variable in the physical-chemical characterization of the banana “Red Dhaka” (*Mussa acuminata*) there is a significant difference; determining that according to Tukey’s test ($p \leq 0.05$), the highest value was T5 (El Empalme; day 5) presented the highest value with 22.5 mg/g, while T3 (La Mana; day 10), It obtained 2.36 mg/g being this the lowest value (Image 9).

Comparing different varieties of banana in terms of their content of polyphenols present in bananas, can serve as a starting point for use of Red Dhaka in the development of functional products that protect consumers from coronary heart disease and others mentioned above. Although there are studies that identify the polyphenols present in the *Musa Cavendish* variety. There are no polyphenol content in other banana varieties nor are there comparisons of the type of polyphenols present in this variety (Márquez, 2014).

Conclusions and Recommendations

The physical characteristics analyzed in the Red Dhaka banana from Maco, indicate that there is no decrease in the length aspects (cm) or the pulp peel ratio (%); unlike firmness, in this aspect of firmness we can observe that as the time elapsed since harvest, the firmness decreases. It should be noted that the firmness of the samples from the geographical location El Empalme, decreases more slowly than those from La Mana.

In the chemical aspect, the variables studied presented significant difference in value ($p \leq 0.05$), the chemical composition varies during the postharvest period, and presents an increase in the content of acidity (%), humidity (%), ash (%) and °Brix, while the pH decreased.

The proximal analysis indicates that there was a significant difference in the variables studied. The

value of polyphenols (mg/g) was higher in the samples from the geographical location of El Empalme, while the percentages of fat, protein and fiber were lower.

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Novelty Statement

This study presents a novel and comprehensive physico-chemical characterization of Maqueño banana (*Musa acuminata*, “Red Dacca”), a variety with unique organoleptic and nutritional properties that has been largely overlooked in scientific literature. Unlike previous studies focused on conventional bananas, this research evaluates the influence of geographical location and post-harvest time on key quality parameters, providing valuable insights into its potential applications in functional food and sustainable agriculture. The findings highlight the superior fiber, protein, and polyphenol content in samples from La Maná, suggesting a slower degradation rate and enhanced nutritional stability compared to other banana varieties. This work establishes a foundational understanding for future industrial and nutritional applications, positioning Maqueño banana as a promising alternative for both local consumption and export markets, while also contributing to post-harvest optimization strategies for emerging banana cultivars.

Author’s Contribution

All the authors were fundamental pillars to carry out the present investigation, each one played a fundamental role in all aspects.

Conflict of interests

The authors have declared no conflict of interest.

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