Proximal and physicochemical characterization of fruits from promising avocado genotypes in three areas in the Dominican Republic

Caracterización proximal y fisicoquímica de frutos de genotipos promisorios de aguacate en tres zonas de República Dominicana

Caracterização proximal e físico-química de frutos de genótipos promissores de abacate de três zonas da República Dominicana

Yulisa Yanilka Alcántara-Marte[1,2]
José Esteban Tejada-Torres[1,2]
Yanilka Yulisa Alcántara-De Tejada[1,2*]

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[1]Universidad Católica del Cibao. Facultad de las Ingenierías. Avenida Universitaria, Esq. Av. Pedro A. Rivera, Apartado No. 401, La Vega, República Dominicana.
[2]Universidad ISA. Facultad de Ciencias Agroalimentarias y del Ambiente. Av. Pte. Antonio Guzmán Fernández, Km. 5½, La Herradura, Santiago de Los Caballeros, República Dominicana. C. P. 51000.

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Abstract

Characterization is one of the main factors to be considered for the use of any raw material to be industrialized and commercialized, and its quality depends on its origin. The objective of this research was to evaluate the fruit characteristics of promising avocado genotypes in the Dominican Republic, for which two studies were carried out. The first study evaluated the effect of genotype (Popenoe, Criollo, and Hass) and the second evaluated the effect of production area (north, central, and southeast Dominican Republic) on proximal (moisture, protein, lipid, and ash content) and physicochemical (titratable acidity, pH, water activity (aw), and soluble solids) characteristics of avocado pulp. Completely randomized designs with four replicates per study factor were performed. An analysis of variance was carried out, and Tukey's test was applied with a reliability of 95 %. The results show that fat, protein, and pH can vary according to genotype. Criollo avocados had lower fat content (6.40 %) and their protein percentage was statistically similar ($p<0.05$) to Hass and higher than Popenoe. The pH ranged from 5.96 (Criollo) to 6.98 (Hass). Production areas can influence the protein content, titratable acidity, and water activity (aw) in avocados. Those with the highest protein content are produced in the southeast, while those with the lowest acidity and highest water activity (aw) are produced in the central zone. These results corroborate the need to characterize genotypes and the origin of raw materials for industrialization and commercialization.

*Corresponding author: yanilkaalcantara@hotmail.com

Resumen

La caracterización es uno de los principales factores a considerar para el aprovechamiento de toda materia prima a industrializar y comercializar y la calidad depende de su procedencia. El objetivo de esta investigación fue evaluar las características de frutos de genotipos promisorios de aguacate en República Dominicana, para lo cual se realizaron dos estudios. En el primero se evaluó el efecto del genotipo (Popenoe, Criollo y Hass) y, en el segundo, la zona de producción (norte, central y sureste de República Dominicana) sobre características proximales (contenido de humedad, proteínas, lípidos y cenizas) y fisicoquímicas (acidez titulable, pH, actividad del agua (aw) y sólidos solubles) de la pulpa de aguacate. Se emplearon diseños completamente al azar con cuatro repeticiones por factor de estudio. Se realizó un análisis de varianza y se aplicó la prueba de Tukey con una confiabilidad de 95 %. Los resultados muestran que la grasa, proteína y pH pueden variar según el genotipo. Los aguacates criollos presentaron menor contenido de grasa (6,40 %) y su porcentaje de proteína fue similar ($p<0,05$) al contenido en Hass y mayor que en el Popenoe. El pH estuvo entre 5,96 (criollo) y 6,98 (Hass). Las zonas de producción pueden influir en el contenido de proteínas, acidez titulable y aw en el aguacate. En el Sureste se producen los de mayor contenido proteico y en la zona Central aquellos menos ácidos y con mayor aw. Estos resultados corroboran la necesidad de caracterizar los genotipos y la procedencia de la materia prima para su industrialización y comercialización.

Palabras clave: *Persea americana*, Criollo, Popenoe, Hass, proteína, grasa, acidez, pH.

Resumo

A caraterização é um dos principais factores a ter em conta para a utilização de qualquer matéria-prima a ser industrializada e comercializada, sendo que a qualidade depende da sua origem. O objetivo desta investigação foi avaliar as caraterísticas de genótipos promissores de abacateiro na República Dominicana, para o qual foram realizados dois estudos. O primeiro estudo avaliou o efeito do genótipo (Popenoe, Criollo e Hass), e o segundo, o efeito da zona de produção (norte, centro e sudeste da República Dominicana) nas caraterísticas proximais (humidade, proteínas, lípidos e cinzas) e físico-químicas (acidez titulável, pH, aw e sólidos solúveis) da polpa do abacate. Foram utilizados desenhos completamente aleatórios com quatro réplicas por fator de estudo. Foi efectuada uma análise de variância e aplicado o teste de Tukey com uma fiabilidade de 95 %. Os resultados mostram que o teor de gordura e proteína e o pH podem variar de acordo com o genótipo. Os abacates criollos apresentam um menor teor de gordura (6,40 %) e sua porcentagem de proteína é estatisticamente semelhante à do Hass e superior à do Popenoe. O pH variou de 5,96 (Criollo) a 6,98 (Hass). As zonas de produção podem influenciar o teor de proteínas, a acidez titulável e a aw nos abacates. Os abacates com maior teor de proteína são produzidos na região Sudeste e os com menor acidez e maior aw na região Central. Estes resultados corroboram a necessidade de caraterizar os genótipos e a origem das matérias-primas para a industrialização e comercialização.

Palavras chave: *Persea americana*, Criollo, Popenoe, Hass, proteína, gordura, acidez, pH.

Introduction

Avocado (*Persea americana* Mill) belongs to the family Lauraceae (Satriana *et al*., 2019). It is a subtropical/tropical fruit with a creamy texture, peculiar flavor and high nutritional value (Tesfaye *et al*., 2022), particularly rich in fatty acids such as oleic and palmitic, minerals and vitamins (Zakaria, 2021), and known for its high content of bioactive compounds such as ascorbic acid, vitamin E, soluble phenolics and carotenoids (Tesfaye *et al*., 2022). Due to the presence of the aforementioned compounds and many other phytochemicals, this fruit has shown numerous medicinal properties, including antimicrobial, anti-inflammatory, analgesic, antihypoglycemic, antihypertensive, antihepatotoxic, anticonvulsant, and vasorelaxant effects (Zakaria, 2021).

In the commercial field, according to Ramírez-Guerrero *et al*. (2023), avocado is one of the most popular fruits in the international market. According to the Food and Agriculture Organization of the United Nations (FAO, 2024), its production has increased worldwide, standing out as a nutritious and versatile food. Furthermore, it is of great interest in the food industry, given its high richness in fats, proteins, vitamins, and phenolic compounds (Tesfaye *et al*., 2022; Zakaria, 2021). Additionally, it has a wide range of uses, including industrialized products: pulps as a base for spreadable, fresh, refrigerated, or frozen products, and obtaining oil, among others.

In the Dominican Republic, avocado production has shown steady growth, contributing to food security and the rural economy (FAO, 2024). The production of this fruit in the country has gained significant importance due to its growing demand in both local and international markets. D.R., is the third country in avocado production (after Mexico and Colombia), with 1,016,834.74 t, according to the latest FAO statistics for 2023 (FAO, 2025). These statistics also indicate that the avocado harvested area in the country was 47,886 ha, being higher than in the previous 5 years; while the yield was 21,234.4 $kg.ha^{-1}$ (FAO, 2025). Data from the Ministry of Agriculture of the Dominican Republic (MA, 2025) show that in 2024, an area of 8,027.81 ha of avocado was planted in the country, and 55,468.33 ha were harvested, obtaining a production of 2,701,537.5 t, of which 63,345.3 t were exported.

With approximately 20 avocado genotypes, the Dominican Republic offers producers a wide range of alternatives. However, this abundance of options makes it difficult to choose the genotype. Among the main avocado varieties cultivated in the country are Semil-34, Hass, Criollo or local, Popenoe, Fuerte, Simmonds, Pollock, and Carla (Sánchez-Rosario *et al*., 2025).

The genetic diversity of avocados cultivated in the Dominican Republic implies their corresponding adaptations to the climatic, edaphic, and other agroecological characteristics of the different production areas. In the north zone, a humid tropical climate predominates, and the soils are very fertile. In the southeast, a humid tropical climate also predominates, and the soils are moderately fertile, while in the central zone, a cool and varied climate prevails with very fertile soils (Payano-Almánzar and Rodríguez, 2018).

The agronomic management of avocado in the Dominican Republic varies according to the production area and local conditions. In areas where forests have been converted into orchards and where there is greater heterogeneity in vegetation structure, the size of the farms and the design of the plantation influence management practices such as soil conservation, crop arrangement and pruning; in regions

with water limitations or particular microclimates, water availability and technical constraints have a decisive influence on fertilization intensity and irrigation strategies adopted (Young *et al*., 2023; Torres-Quezada *et al*., 2025).

It has been argued that genetic variability can impact fruit quality characteristics, being fundamental for market competitiveness and consumer acceptance (Salazar *et al*., 2016). The physicochemical characteristics of avocado, such as soluble solids content, pH, acidity, and nutrient profile, are important indicators of fruit quality and directly affect taste and texture. There are different studies on avocado; however, most focus on general aspects, while specific characterization by genotype and region is scarce. In the Dominican Republic, this lack of information limits the use of the commercial and agro-industrial potential of its varieties. Therefore, the objective of this research was to characterize the physicochemical and proximal properties of the fruits from three of the main genotypes of native avocados cultivated in the north, southeast, and central regions of the Dominican Republic. The information generated will guide the technical sectorization of national production, an aspect currently not regulated by the Ministry of Agriculture for this species. Characterization by genotype and region would allow for the identification of optimal cultivation areas, facilitate agricultural planning, reduce post-harvest losses, and optimize the quality of the fruit destined for both the domestic and export markets. In this sense, the study provides technical evidence that can be considered in future strategies of agro-productive management and territorial differentiation of avocado production in the country.

Materials and methods

Study location

This research was carried out at the Research and Experimentation Laboratory (19°13'4" N, 70°31'08" W, 96.82 m.a.s.l.) of the Catholic University of Cibao (UCATECI), La Vega, Dominican Republic.

Plant material

Avocado fruits of the Popenoe, Hass, and Criollo morado varieties were harvested directly from the trees at a commercially mature physiological stage, without bruises or rot, from each of the selected farms in the main production areas of the Dominican Republic (north, southeast, and central). For each genotype, 4 fruits were collected, totaling 144 fruits. These were transported in plastic baskets to UCATECI on the same day of harvest. The collection dates were August for the north zone and September for the southeast and central zones.

Sample preparation

In the research and experimentation laboratory of UCATECI, the fruits were weighed, washed, and disinfected with drinking water and sodium hypochlorite (100 $mg.L^{-1}$, for 3 min) and dried using absorbent paper. The fruits were manually peeled and homogenized using a blender (Ninja BL780C 30, China) for 2 minutes.

For physicochemical analyses, the 144 fruits collected were grouped into 12 samples (n=12); each sample consisted of homogenizing the pulp of 12 fruits harvested by each farm or producer, genotype, and study area.

Proximal composition

The content of moisture, fat, protein, and ash was determined using the protocols of the Association of Official Analytical Chemists (A.O.A.C., 1990).

Physicochemical characteristics

Titratable acidity (TA) was determined using the volumetric titration method (A.O.A.C., 1990), expressing the results as a percentage of citric acid. Ionic acidity (pH) was measured by potentiometry using a pH meter (Thermo Scientific Orion Star A211, Indonesia). Water activity (aw) with a hygrometer (Rotronic Hygro Palm HP-23, Switzerland) and soluble solids (SS) by refractometry (Sper Scientific IP65 digital refractometer, China).

Experimental design and statistical analysis

The study consisted of two phases:

Phase 1: A completely randomized design was used, and the effect of genotype on the proximal and physicochemical characteristics of avocado fruits was evaluated. Four replications were performed per study factor (genotype), totaling 12 experimental units. In phase 2, a completely randomized design was used, and the effect of the production area on the response variables indicated for phase 1 was evaluated. Four replications were performed per study factor (production area), totaling 12 experimental units.

For the analysis of the results obtained, ANOVAS were performed, and the means were separated using Tukey's test at a 95 % confidence level, employing the Statistix statistical package for Windows, version 8.0 (Analytical Software, 2003).

Results and discussion

Proximal composition

The analysis of variance performed for the proximal characteristics of avocado revealed that the fat and protein content may vary according to the genotype (Table 1). Hass and Popenoe avocados had a higher fat content than Criollo avocados, respectively, with the Hass and Criollo genotypes being statistically different. In turn, these two genotypes showed the highest percentages of protein and were statistically different ($p<0.05$) from Popenoe.

Table 1. Proximal composition of avocado fruits of three genotypes cultivated in three areas of the Dominican Republic.

Geno-type	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
		Media (DS)		
Criollo	81.00^{a}	6.40^{b}	1.26^{a}	0.48^{a}
	(2.43)	(0.89)	(0.14)	(0.13)
Popenoe	81.45^{a}	8.43^{ab}	0.83^{b}	0.48^{a}
	(3.84)	(1.98)	(0.21)	(0.48)
Hass	80.75^{a}	9.82^{a}	1.66^{a}	0.49^{a}
	(1.10)	(1.28)	(0.32)	(0.09)
Study area	**Moisture (%)**	**Fat (%)**	**Protein (%)**	**Ash (%)**
		Media (DS)		
North	79.47^{a}	9.29^{a}	0.77^{b}	0.53^{a}
	(2.90)	(2.39)	(0.25)	(0.13)
Southeast	80.87^{a}	8.11^{a}	1.46^{a}	0.48^{a}
	(1.76)	(2.09)	(0.31)	(0.11)
Central	83.43^{a}	7.57^{a}	0.89^{b}	0.40^{a}
	(3.93)	(1.23)	(0.18)	(0.05)

Different letters in the same column indicate differences between the means for each study factor ($p<0.05$), in the Tukey's test.

Protein content is the proximal characteristic of the avocados evaluated that undergoes variations in relation to the production area. In this case, it is observed that avocados with the highest content of this nutrient are produced in the southeast zone (Table 1).

The results obtained in this research guide exporters within the value chain toward selecting the Hass genotype for commercialization in premium fresh fruit export markets (Hammami *et al*., 2024) or as avocado chips, given that its high fat content implies better flavor and creaminess (Fonseca Duarte *et al*., 2016).

At the industrial level, for oil processors, the Hass and Popenoe genotypes offer higher fat yields, so Criollo could be destined for local pulp markets or less demanding products.

According to Ford *et al*. (2023), in general, the proximal composition of avocado pulp is 61-77 % moisture, 13.5-24 % lipids, 1.05-2.04 % proteins, and 3.0-12.2 % carbohydrates. However, several authors have explained that the differences in the characteristics, not only proximal, but also physicochemical, organoleptic and quality in general of avocados can be attributed to environmental factors such as climate, soil, latitude and altitude, as well as to the region of origin, the variety in question, their degree of ripeness and agronomic management (Chávez *et al*., 2024; Salazar *et al*., 2016).

Nasri *et al*. (2023) evaluated eight varieties of Moroccan avocado (Ettinger, Fuerte, Hass, Reed, Zutano, Bacon, Maluma Hass, and Choquette) and determined significant differences between the eight varieties studied in moisture content (57.88 to 84.71 %), fat content (8.41 to 57.88 %), ash (0.57 to 1.37 %), and protein content (5.7 to 8.61 %). Regarding the Hass genotype, they reported 76.03 % moisture, 13.45 % oil, 0.99 % ash, and 8.47 % proteins. It can be seen that, except for moisture content, Moroccan Hass avocados are richer in nutrients than Dominican ones, regardless of the area where they are produced, perhaps due to a different fertilization regime. Vinha *et al*. (2013) studied 'Hass' variety avocados produced in the Algarve region, achieving higher fat (43.5 %) and ash (1.77 %) and lower moisture (70.83 %) and protein (1.82 %) contents. On the other hand, in Lavras (Brazil), De Carvalho *et al*. (2021) found moisture levels in the pulp of 'Hass' avocado of 45.8 %, significantly lower than those obtained in this study. In contrast, Ge *et al*. (2017) studied two varieties of avocado (RN-7 and RN-8) in China, and reported 82.85 and 83.59 % moisture, 7.33 and 6.53 % oil, 0.52 and 0.74 % ash, and 0.42 % protein in both varieties, respectively, with the values of moisture and oil being similar to those obtained in this research, while those of ash are slightly higher and those of proteins, lower. In avocados of the Margarida variety, Krumreich *et al*. (2024) found protein ranges between 1.11 and 1.75 %.

According to Meyer and Terry (2010), the lipid content of avocados can comprise between 15 and 30 % of the fresh weight of the fruit, highlighting that these variations depend on the cultivar, season, and growing conditions. These arguments regarding variations in avocado characteristics are corroborated by Fonseca Duarte *et al*. (2016), who indicated that the main climatic requirements of the avocado tree are related to temperature and rainfall and that the varieties present different responses among them.

In the literature consulted, there is varied information on the proximal content of avocados, even though it is the same genotype. For example, according to Ford *et al*. (2023), Hass avocado contains approximately 13.5-24 % oil. On the other hand, Chimuti *et al*. (2021) indicated that the oil content is close to 30 % (depending on the extraction method used). This could be explained by the factors indicated above.

Although climatic seasons in the Dominican Republic are not as clearly defined as in other countries, the southeast zone typically experiences low rainfall; however, no statistically significant differences ($p > 0.05$) in moisture content were observed among the study zones.

The fat content in the fruits evaluated is consistent with that reported by Chimuti *et al*. (2021), who indicated that this content varies from 3 to 30 % depending on the variety of avocado.

Recently, Chávez *et al*. (2024) reported significant differences in the variables evaluated when studying seven native avocado breeds in the city of Parras de la Fuente, Coahuila (Mexico), reporting averages of 3.06 to 13.65 % moisture, 1.33 to 5.21 % ash, 0.54 to 2.21 % protein, and 53.29 to 66.58 % fat.

The high standard deviation recorded in the variables evaluated in this study (Table 1) may be due to the fact that the fruit samples come from different production units in the area, each with different agronomic management practices, resulting in variability in fruit quality. Additionally, microclimatic effects and variations in edaphoclimatic conditions among the production units, among other factors, may have contributed (Méndez Hernández *et al*., 2024).

Physicochemical characteristics

Ionic acidity was the only physicochemical parameter in the samples that varied by genotype ($p<0.05$) (Table 2). Hass and Popenoe avocados presented higher values, statistically different ($p<0.05$) than those recorded for the Dominican Criollo genotype. The range for this variable was between 5.97 and 6.98 %. It was also observed that the production areas studied can influence the titratable acidity and water activity of avocado fruits.

Table 2. Physicochemical characteristics of the pulp of three avocado genotypes cultivated in three areas of the Dominican Republic.

Genotype	TA	pH	Aw	SS
	Media (DS)			
Criollo	0.20^{a}	5.97^{b}	0.96^{a}	9.75^{a}
	(0.05)	(0.57)	(0.00)	(3.57)
Popenoe	0.13^{a}	6.68^{a}	0.97^{a}	6.71^{a}
	(0.05)	(0.23)	(0.01)	(1.59)
Hass	0.11^{a}	6.98^{a}	0,97^{a}	9.58^{a}
	(0.04)	(0.10)	(0.00)	(2.35)
Production area	**TA**	**pH**	**Aw**	**SS**
	Media (DS)			
North	0.18^{a}	6.65^{a}	0.96^{b}	6.87^{a}
	(0.01)	(0.28)	(0.01)	(2.37)
Southeast	0.15^{ab}	6.47^{a}	0.96^{b}	9.66^{a}
	(0.15)	(0.66)	(0.00)	(2.80)
Central	0.08^{b}	6.71^{a}	0.989^{a}	6.55^{a}
	(0.00)	(0.20)	(0.00)	(0.45)

TA: titratable acidity (% citric acid), Aw: water activity, SS: soluble solids (°Brix). Different letters in the same column indicate differences between the means for each study factor ($p<0.05$) according to Tukey's test.

There is scarce information on the physicochemical characterization of avocado; most studies focus on the proximal composition and the evaluation of the lipid fraction, with the determination of fatty acids. Ge *et al*. (2017) studied the physicochemical characteristics of two avocado varieties (RN-7 and RN-8) in China, reporting values of 0.56 % and 0.72 % of glucose and titratable acidity of 1.78 % and 2.63 % of tartaric acid, respectively. In 'Hass' variety avocados produced in the Algarve region (Portugal), Vinha *et al*. (2013) obtained lower TSS values (6.68 °Brix) and 1.07 % tartaric acid. Regarding the relationship between these parameters, Vinha *et al*. (2013) explain that the soluble solids of avocados tend to increase as ripening progresses due to plant biosynthesis and polysaccharide degradation. Conversely, avocado acidity tends to decrease during ripening as a result of respiration or conversion into sugars, since metabolic activity increases and organic acids serve as an energy reserve for the fruit through the Krebs cycle. In their study, TSS exhibited a behavior opposite to acidity. However, this did not occur in the present research. In 'Hass' avocados of American origin, Henríquez Arias *et al*. (2012) reported 5.1 °Brix and 0.04 % citric acid, both values being lower than those obtained in the present study. According to Meyer and Terry (2010), the sugar content of avocados is relatively low, depending on the cultivar, season, and growing conditions. In this regard, Kilaru *et al*. (2015), state that soluble sugars may be the precursors of lipid synthesis in these fruits, implying that the higher the lipid content, the lower the levels of soluble sugar in the pulp, contrary to what was observed in the present research.

Conclusions

The characterization of Dominican avocados revealed that, according to the genotypes, there is variation in the content of fat, protein, and ionic acidity, while production areas can influence the protein content, titratable acidity, and water activity of the avocado. These findings facilitate the identification of avocado genotypes with greater commercial potential and nutritional value according to the specific agroclimatic conditions of the three regions of the country, allowing for a deeper understanding of this agricultural resource and its applications in agroindustry and export.

Future potential research could include the characterization of phytochemicals present in the pulp and seed of Dominican avocados according to genotype and region, irrigation and fertilization trials by genotype and area, and the evaluation of genetic susceptibility to water stress in relation to fat content.

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