



Comparative study of the physico-chemical and bioactive composition of avocado (*Persea americana* Mill.) seed flour from two varieties: commercial (Hass) and regional (Fuerte)

Estudio comparativo de la composición físico-química y bioactiva de harina de semilla de aguacate (*Persea americana* Mill.) de dos variedades: comercial (Hass) y regional (Fuerte)

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Abstract

The avocado industry generates substantial quantities of seeds as a byproduct. Although commonly discarded, avocado seeds constitute a valuable source of dietary fiber, lipids, and bioactive compounds with antioxidant properties, offering considerable potential for food applications. The production of avocado seed flour has emerged as a promising strategy for valorizing agro-industrial residues while developing novel functional ingredients. Accordingly, this study compared the physicochemical characteristics and antioxidant capacity of avocado seed flours obtained from two avocado (*Persea americana* Mill.) varieties: the commercial Hass cultivar and the regional Fuerte cultivar. The evaluated factors were cultivar and fruit maturity stage (13.7 and 5.8 °Brix for Hass and Fuerte, respectively). Fruit samples were collected from Bolívar Canton, Manabí Province, Ecuador. Avocado seeds were dried, milled, and sieved prior to determining pH, moisture, crude fiber, fat, ash, protein, carbohydrate contents, and antioxidant capacity using the ABTS assay. Data analysis comprised descriptive statistics, the Shapiro-Wilk normality test, and Student's *t*-test. Significant differences between cultivars were observed for pH, moisture content, fat, and ash contents ($P < 0.05$). In contrast, no significant differences were detected for crude fiber ($P > 0.083$), carbohydrates ($P > 0.131$), crude protein ($P > 0.100$), or antioxidant capacity ($P > 0.098$), indicating comparable functional attributes between the two flours. These findings suggest that cultivar type influences technological properties associated with acidity and moisture-related stability, whereas the functional contributions of dietary fiber and antioxidant compounds remain largely conserved. The observed equivalence supports the use of either cultivar as a sustainable source of bioactive compounds for the formulation of dietary supplements and functional foods.

Keywords: *Persea americana*, avocado seed flour, antioxidant capacity, physico-chemical properties, agro-industrial waste valorization, functional ingredients.

Resumen

La agroindustria del aguacate genera grandes volúmenes de semillas como subproducto. Este material, lejos de constituir un recurso subutilizado, concentra fibra, lípidos y compuestos con actividad antioxidante susceptibles de aprovechamiento por la industria alimentaria. Su transformación en harina representa una alternativa promisorio para reducir el desperdicio agroindustrial y desarrollar nuevos ingredientes con potencial funcional. Con ese fundamento, el estudio comparó la composición físico-química y bioactiva de la harina de semilla de aguacate *Persea americana* Mill.) en dos variedades: la comercial Hass y la regional Fuerte. Los factores considerados fueron la variedad y el grado de madurez del fruto (13,7 y 5,8 °Brix en Hass y Fuerte, respectivamente). Las muestras procedieron del cantón Bolívar, en Manabí, Ecuador. Una vez secadas, molidas y tamizadas las semillas, se determinaron pH, humedad, fibra, grasa, ceniza, proteína y carbohidratos, además de la capacidad antioxidante mediante el método ABTS. El análisis estadístico combinó medidas descriptivas, la prueba de Shapiro-Wilk y la *t* de Student. Las variedades difirieron de manera significativa en pH, humedad, grasa y ceniza ($P < 0,05$). No ocurrió lo mismo con la fibra ($P > 0,083$), los carbohidratos ($P > 0,131$), la proteína bruta ($P > 0,100$) ni los antioxidantes ($P > 0,098$), donde las harinas resultaron equivalentes en estos parámetros. Tales resultados indican que la variedad modifica propiedades tecnológicas como la acidez y la estabilidad asociada a la humedad; mientras que, el aporte funcional de fibra y antioxidantes se conserva. Esa equivalencia respalda el empleo de cualquiera de las dos variedades como fuente de compuestos bioactivos en suplementos o alimentos funcionales.

Palabras clave: *Persea americana*, antioxidantes, harina de semilla, valorización de residuos, propiedades físico-químicas.



Introduction

In recent decades, agro-industrial residues have ceased to be regarded as mere waste and have become a subject of research. Avocado processing illustrates this shift: once the pulp (mesocarp) has been obtained, the peel (epicarp) and seed remain-fractions that retain nutritional and functional compounds that are still underused (Cheikhoussef and Cheikhoussef, 2022). The avocado (*Persea americana* Mill.) is native to Mexico and Central America and is among the most commercially important fruits in the Lauraceae family. Two varieties are grown most extensively in Ecuador: 'Fuerte,' intended for domestic consumption, and 'Hass,' produced mainly for export.

The avocado industry focuses on pulp-derived products such as guacamole, dehydrated pulp for spreads, and oil. This approach uses only one part of the fruit and discards the peel and seed, which together represent a considerable portion of its biomass. When accumulated without a defined destination, these byproducts create a management problem and, at the same time, an opportunity, because they retain biomolecules of interest that are mostly discarded (Ávila et al., 2023).

Of these byproducts, the seed has the greatest potential. It provides proteins, lipids, starch, and fiber, as well as bioactive compounds with potential health and food applications (Ávila et al., 2023). Transforming it into flour is one of the most widely studied options. In animal production, including up to 10% avocado seed flour in lamb diets promoted growth and was proposed as a partial substitute for cereals (Bugarín et al., 2021).

Despite this interest, information on avocado seed flour remains limited, particularly with respect to its physico-chemical and functional properties and differences among varieties. Valorization of agro-industrial byproducts is currently one of the most relevant strategies for promoting sustainable food systems and circular-economy models. In this context, avocado seeds are a residual biomass with high potential for producing functional ingredients because of their dietary fiber, resistant starch, phenolic compounds, and antioxidant metabolites. Recovering and transforming these residues reduces the environmental burden associated with agroindustry and generates new value-added products for the food, pharmaceutical, and cosmetics sectors (Calderón-Oliver and López-Hernández, 2020; Cheikhoussef and Cheikhoussef, 2022; Aguilar-Vásquez et al., 2024).

Research has focused more on extracting starch and bioactive compounds than on characterizing the flour and comparing cultivars (Ávila et al., 2023). Filling this gap is necessary to guide specific applications of the byproduct. Accordingly, this study compared the physicochemical composition and antioxidant capacity of avocado seed flour from the Hass and Fuerte varieties.

Materials and methods

The study used flour obtained from the seeds of two avocado varieties: the commercial Hass and the regional Fuerte. Fruit maturity was determined by refractometry, measuring total soluble solids in the pulp with a digital refractometer (Astudillo-Ordóñez and Rodríguez, 2018); values were 13.7 °Brix for Hass and 5.8 °Brix for Fuerte. Fruits were selected for uniform color and size and the absence of blemishes, mechanical damage, and fungal infections. Hass avocados were purchased from supermarkets in central Cacha (Manabí); Fuerte avocados were harvested in the rural area of Membrillo (1°12' S, 80°22' W), Manabí, Ecuador.

Ripe fruits were cut in half to remove the seeds. Each seed was washed, disinfected, and surface-dried with absorbent paper to remove adhering pulp. The seeds were grated with a conventional kitchen grater, and the material was immediately dried so that heat would limit enzymatic browning. Drying was carried out in a convection oven at 70 °C for one hour. The dried product was pulverized in a Grinder-brand mill and sieved through a No. 30 mesh, equivalent to 600 µm. This step homogenized particle size and removed the coarser fractions. The resulting particle size was coarser than that of conventional baking flours, whose mean size is approximately 50-150 µm.

Physicochemical characterization was conducted in the laboratories of the Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López (ESPAM MFL), in accordance with the official methods of AOAC International (2019). pH was measured by potentiometry (method 943.02); moisture by gravimetry after oven-drying to constant mass (925.10); ash by incineration in a muffle furnace at 550 °C (923.03); fat by ether extraction in a Soxhlet system (920.39); and crude fiber by acid-alkali digestion followed by incineration (962.09).

Total polyphenols, a variable commonly measured alongside antioxidant capacity, were not quantified in this study. For reference, previous research on avocado seed powder reported values that varied considerably by variety and extraction method; Siol and Sadowska (2023), for example, recorded an average of 62.1 mg gallic acid equivalents per gram. This omission is acknowledged as a limitation, and including this analysis in future research is recommended because it would enable more precise associations between chemical composition and the bioactivity of the flours studied (Kosińska et al., 2012; Tremocoldi et al., 2018).

Antioxidant capacity was evaluated using the ABTS method described by Re et al. (1999) in the chemistry laboratory of Universidad Técnica de Manabí (UTM), Chone extension. The ABTS•+ radical cation was generated by reacting 7 mM ABTS

with 2.45 mM potassium persulfate; the mixture was kept in the dark at room temperature for 12-16 hours. The radical solution was adjusted with ethanol to an absorbance of 0.70 ± 0.02 at 734 nm. After the sample was added, absorbance was read at 734 nm after six minutes of reaction, and results were expressed as μmol Trolox equivalents per gram of flour using a Trolox calibration curve.

Data were summarized using descriptive statistics (mean, standard deviation, and coefficient of variation). Variable normality was assessed with the Shapiro-Wilk test, and varieties were compared using Student's t-test for independent samples at a significance level of 0.05.

Three replicates were used for each analysis. For each replicate, five Fuerte seeds were used, whereas the number of Hass seeds was doubled because of their size and biomass, for a total of 10

seeds per replicate. Overall, 105 Fuerte seeds and 210 Hass seeds were used to produce the flour.

Results and discussion

Comparison of the Fuerte and Hass varieties revealed relevant differences in their physicochemical characteristics (table 1). pH was higher in Hass (5.98) than in Fuerte (5.45), with statistically significant differences ($P < 0.05$), making Hass the less acidic flour. This result is noteworthy because pH determines much of a flour's technological behavior: it influences protein solubility and water-absorption capacity, which decrease near the isoelectric point; affects the temperature and degree of starch gelatinization; and influences emulsion stability and the activity of enzymes responsible for browning. Consequently, a somewhat less acidic flour such as Hass may hydrate, gel, or develop color differently during processing.

Table 1. Physico-chemical analysis of avocado seed flour from the Hass and Fuerte varieties.

Variety	pH			Moisture (%)			Fiber (%)			Fat (%)			Ash (%)		
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
Fuerte	5.45 b	0.015	0.28	5.59 b	0.125	2.23	2.54 a	0.345	13.57	2.27 b	0.010	0.78	4.18 a	0.110	2.60
Hass	5.98 a	0.023	0.38	11.10 a	0.050	0.45	1.99 a	0.238	11.96	2.50 a	0.240	9.71	2.06 b	0.010	0.76

Note: Values are means of three replicates. pH is dimensionless; moisture, fiber, fat, and ash are expressed as percentages. SD = standard deviation; CV = coefficient of variation. Within each parameter, unlike letters indicate a significant difference.

Regarding moisture, Hass reached 11.1%, compared with 5.59% for Fuerte (Table 1), also with statistically significant differences ($P < 0.05$). The Hass value fell within the reported range for avocado seed flours, approximately 7-14% (Ávila et al., 2023). This moisture content of 11.1% should be interpreted cautiously because it may be influenced by factors inherent to processing and the analytical conditions. High moisture shortens flour shelf life, increases susceptibility to mold growth and microbial activity, and promotes caking during storage. At only 5.59%, Fuerte avocado flour offers a clear storage advantage in this respect, suggesting that drying should be adjusted to bring both varieties to a comparably low moisture level.

With respect to fat content, Hass had a slightly higher value than Fuerte (2.50% versus 2.27%), and the difference was statistically significant ($P < 0.05$). Hass flour also showed a higher coefficient of variation (9.71% versus 0.78% for Fuerte); in other words, its fat values were less homogeneous among replicates (table 1). Both figures were in the low range described by Ávila et al. (2023), who documented lipid contents ranging from 0.33-2.71% to 14.10-15.73% in avocado seed flours. This broad range depends mainly on processing: extraction and defatting procedures, washing, particle size, and variety explain why some studies reported values higher than those obtained here.

For fiber, Fuerte exceeded Hass (2.54% versus 1.99%), although the difference was not significant ($P > 0.083$; table 1). Both values were below the 21.6% reported by Siol and Sadowska (2023) for avocado seed powder. The difference can be explained by production conditions: the fiber-isolation method, washing in

alkaline solutions, degree of defatting, and particle size decisively influence the quantified fiber. Flour obtained by simple drying and milling, as in this study, retains less concentrated fiber than powder subjected to purification treatments.

Ash content was higher in Fuerte (4.18%) than in Hass (2.06%), with significant differences ($P < 0.05$; table 1); both values were close to the mean of 3.82% reported by Punia et al. (2022). NTE INEN 616 established a maximum ash content of 0.8% for general-purpose wheat flour, a limit met by neither variety. It should be clarified, however, that this standard specifically regulates wheat flour intended for human consumption, not flours made from plant byproducts; the comparison therefore serves as a reference rather than a directly applicable regulatory criterion.

The higher ash content does not disqualify the flour for food use. In seed flour, ash reflects the mineral richness of the material, including calcium, iron, magnesium, and zinc (Ávila et al., 2023). Rather than a drawback, this characteristic positions the flour as a potential mineral-enrichment ingredient, provided it is used as a supplement and not as a direct replacement for refined wheat flour. Ash level may also affect attributes such as color, viscosity, and final-product stability, which should be evaluated in specific applications.

Statistical analysis based on the P values from the tests (table 2) identified the variables that differed significantly between the Fuerte and Hass varieties. pH, moisture, fat, and ash had P values below 0.05, confirming statistical differences. This means that the observed contrasts in physicochemical composition—lower



pH and higher moisture in Hass, compared with higher mineral content in Fuerte—were consistent and not attributable to chance.

Table 2. Statistical analysis of the physicochemical composition of seed flour from two avocado varieties, 2025.

Variable	Independent-samples tests		Conclusion
	P value	Hypothesis decision	
pH	0.00000481421	Rejected	Statistically significant differences
Moisture	0.000000238082	Rejected	Statistically significant differences
Fiber	0.0831763	Accepted	No significant difference between means
Fat	0.000899078	Rejected	Statistically significant differences
Ash	0.00000451901	Rejected	Statistically significant differences
Carbohydrates	0.131	Accepted	No significant difference between means
Crude protein*	0.100	Accepted	No significant difference between means

Note: *For crude protein, the Fuerte variety failed the Shapiro-Wilk test ($P < 0.001$; two of its three values were identical, which strongly affected this statistic at $n=3$). The Mann-Whitney U test was therefore used instead of Student's t-test. With three replicates per group, the smallest P value attainable by this test in a two-tailed comparison was 0.100; the result should therefore not be interpreted as evidence of a true absence of difference (see table 4).

In contrast, fiber had $P > 0.083$, above the significance threshold of 0.05, indicating no statistically significant difference between the varieties for this component.

Figure 1 complements the preceding analyses and compares the pH of avocado seed flours from the Fuerte and Hass varieties. Fuerte had lower pH values, concentrated around 5.4–5.5, whereas Hass had clearly higher values, close to 6.0. This reflected a marked difference in flour acidity: Fuerte was more acidic than Hass. Both boxes were narrow, indicating low data dispersion and therefore good measurement consistency.

Figure 2 compares the moisture content of avocado seed flours from the Fuerte and Hass varieties. Fuerte had lower moisture values, concentrated around 5.4–5.5%, whereas Hass had

significantly higher values, close to 11%. This shows a marked difference between the two flours: Hass seed flour retained approximately twice as much moisture as Fuerte seed flour.

The observed differences in residual moisture could be attributed to intrinsic variations in seed structural composition, particularly the proportion of polysaccharides and the water-retention capacity of the cell matrix. Several studies have indicated that moisture contents below 10% favor microbiological stability and reduce deterioration reactions during prolonged storage of plant flours (Punia et al., 2022).

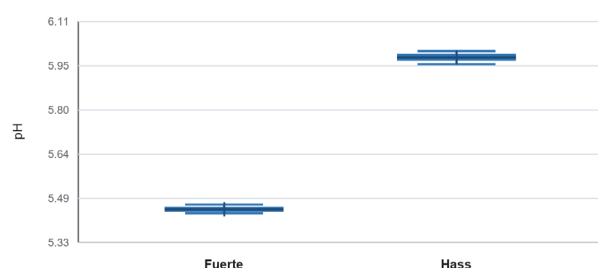


Figure 1. Box-and-whisker plot of pH in avocado (*Persea americana* Mill.) seed flour from the Fuerte and Hass varieties. The horizontal line inside each box represents the median, the (+) symbol indicates the mean, and the box limits correspond to the interquartile range.

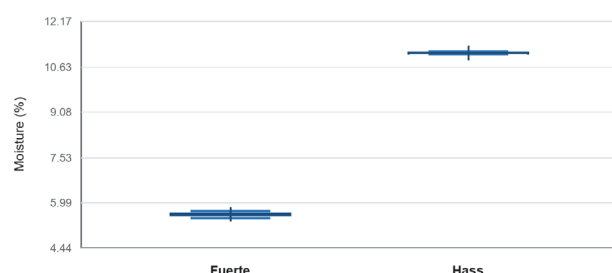


Figure 2. Box-and-whisker plot of moisture content in avocado (*Persea americana* Mill.) seed flour from the Fuerte and Hass varieties. The horizontal line inside each box represents the median, the (+) symbol indicates the mean, and the box limits correspond to the interquartile range.

Data dispersion was low in both varieties, reflecting consistency in the measurements. Astudillo and Rodríguez (2018) likewise

described how this moisture difference could affect technological aspects such as stability, shelf life, and susceptibility to microbial deterioration, making Fuerte flour potentially more stable in storage because of its lower water content.

Figure 3 compares ash content between the Fuerte and Hass varieties. Fuerte had higher values, with a median close to 4.1 and relatively low dispersion, indicating a greater ash concentration and consistent data. In contrast, Hass had considerably lower values, with a median close to 2.0 and little variability, indicating lower and more uniform ash content.

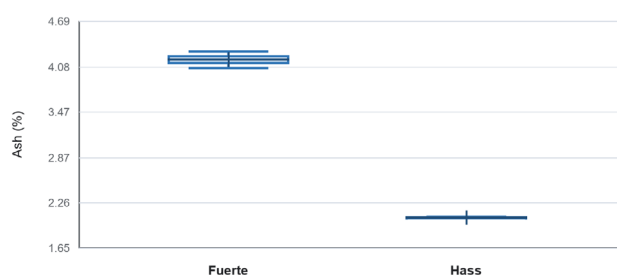


Figure 3. Box-and-whisker plot of ash content in avocado (*Persea americana* Mill.) seed flour from the *Fuerte* and *Hass* varieties. The horizontal line inside each box represents the median, the (+) symbol indicates the mean, and the box limits correspond to the interquartile range.

The ash concentration observed in Fuerte could be associated with a greater relative accumulation of essential minerals, including potassium, calcium, magnesium, iron, and zinc, which have previously been identified in avocado seeds. Specific quantification of these minerals using instrumental techniques would establish the nutraceutical potential of this byproduct more precisely (Punia et al., 2022).

Figure 4 shows the behavior of fat content in both varieties. In Fuerte, values clustered around 2.27%, with minimal dispersion that reflected a low and very stable fat level. Hass reached a median close to 2.50% and a somewhat wider range, indicating slightly higher content and some variability among samples. Although modest, the difference placed Hass above Fuerte. Both results agreed with Ávila et al. (2023), who reported low lipid contents in avocado seed flour, between 0.33% and 2.71% depending on the variety and analytical procedure, and noted that this low fat level reduced susceptibility to rancidity and improved product stability during storage.

The results showed that Fuerte avocado seed flour had a higher antioxidant concentration (197.302 $\mu\text{mol Trolox}$

equivalents·g⁻¹ flour) than Hass (184.304 $\mu\text{mol Trolox}$ equivalents·g⁻¹ flour; Table 3). Both values were below those reported by Siol and Sadowska (2023), who found an antioxidant capacity of 122.4 mmol Trolox·100 g⁻¹ (approximately 1,224 $\mu\text{mol}\cdot\text{g}^{-1}$) in avocado seed powder evaluated with the same ABTS method; the gap is mainly attributable to differences in extraction conditions, solvent, and the matrix analyzed. The statistical test indicated that the difference between varieties was not significant at the 95% confidence level ($P>0.097544$). Statistically, the two flours had similar antioxidant contents, so the observed variation could be attributed to chance rather than a real varietal effect. The coefficients of variation were also low (4.30% for Fuerte and 3.30% for Hass), reflecting good measurement homogeneity.

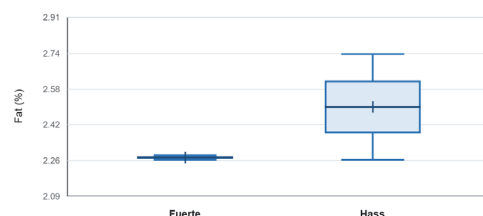


Figure 4. Box-and-whisker plot of fat content in avocado (*Persea americana* Mill.) seed flour from the *Fuerte* and *Hass* varieties. The horizontal line inside each box represents the median, the (+) symbol indicates the mean, and the box limits correspond to the interquartile range.

Table 3. Antioxidant analysis of avocado seed flour from the Hass and Fuerte varieties.

Variable	Variety	Mean	SD	CV (%)
Antioxidants ($\mu\text{mol Trolox}$ equivalents/g flour)	Fuerte	197.302 a	8.49465	4.30541
	Hass	184.304 a	6.08919	3.30389

The absence of significant differences between Fuerte and Hass permits a straightforward interpretation: neither variety outperformed the other as a source of antioxidants. Fuerte recorded a somewhat higher mean (197.302 versus 184.304 $\mu\text{mol Trolox}$ equivalents·g⁻¹), but this numerical advantage did not withstand statistical testing because it fell within the margin attributable to chance. Variety therefore did not determine the flour's antioxidant contribution. This finding has a practical consequence: if the seed is intended for use as a functional ingredient, cultivar selection may be based on availability, cost, or yield without sacrificing antioxidant capacity. Low measurement dispersion, with

coefficients of variation below 5% in both samples, strengthened confidence in this result.

Crude protein was higher in Fuerte (5.03%) than in Hass (3.13%; Table 4). The Shapiro-Wilk test did not reject normality for Hass ($P>0.637$), but did reject it for Fuerte ($P<0.001$); the comparison was therefore conducted with the Mann-Whitney U test rather than Student's t-test (Table 2). The result ($P>0.100$) did not reach the 0.05 threshold, meaning that, strictly speaking, no significant difference between the means was confirmed, even though all three Fuerte values exceeded all three Hass values. This apparent contradiction is explained by sample size: with only three replicates per group, the smallest P value this test can attain in a two-tailed comparison is exactly 0.100. The result therefore reflects a statistical limitation rather than a true absence of difference, and the determination should be repeated with more samples before concluding that the varieties provide similar amounts of protein.

Table 4. Crude protein and carbohydrates in avocado seed flour from the Hass and Fuerte varieties.

Variable	Variety	Mean	SD	CV (%)
Crude protein (%)	Fuerte	5.03	0.06	1.15
	Hass	3.13	0.15	4.88
Carbohydrates (%)	Fuerte	84.04	4.38	5.21
	Hass	79.25	0.11	0.14

Note: Crude-protein values are from Analysis Report No. 274 of the Animal Nutrition Laboratory, Faculty of Agricultural Sciences, Central University of Ecuador (n=3 per variety; Kjeldahl method, NTE INEN-ISO 5983-1, 2014); the variety identified as "V. Regional" in that report corresponds to Fuerte. Carbohydrate values are from an additional record (n=3 per variety). SD = standard deviation; CV = coefficient of variation.

Regarding carbohydrate content, Fuerte recorded a mean of 84.04%, compared with 79.25% for Hass (Table 4). Both groups passed the Shapiro-Wilk test ($P>0.159$ and $P>0.174$, respectively), and Levene's test detected no difference between variances ($P>0.323$), so Student's t-test for equal variances was applied (Table 2). The result ($t(4)=-1.898$; $P>0.131$) also failed to reach the 0.05 threshold, and no significant difference between varieties was confirmed. Dispersion in Fuerte (SD=4.38; CV=5.21%) was notably greater than in Hass (SD=0.11; CV=0.14%), mainly because one of the three replicates (89.08%) differed from the other

two (81.16% and 81.89%). This variability widened the confidence interval for the difference between means and reduced the test's ability to detect real differences; it would therefore also be imprudent to rule out a varietal difference without first increasing the number of replicates.

Growing interest in functional foods has encouraged the incorporation of flours made from plant byproducts because of their ability to increase dietary fiber, antioxidants, and micronutrients in food formulations. In particular, avocado seed flour has shown potential for use in baked products, nutritional supplements, and enriched blends, improving the nutritional profile without significantly affecting certain technological properties when used at moderate substitution levels (Nayak et al., 2022).

Conclusion

The study demonstrates that avocado variety significantly influences several physicochemical attributes of flour obtained from its seeds. Hass had a higher pH (5.98), greater moisture content (11.10%), and a slightly higher fat content (2.50%), whereas Fuerte had higher ash (4.18%) and crude protein (5.03%) concentrations and an average antioxidant capacity of 197.30 $\mu\text{mol Trolox equivalents} \cdot \text{g}^{-1}$ flour. Differences in pH, moisture, fat, and ash were statistically significant ($P<0.05$), whereas fiber, carbohydrates, protein, and antioxidant activity showed no differences between cultivars.

Unlike the preceding parameters, fiber and antioxidant capacity showed no significant differences between the two varieties ($P>0.083$ and $P>0.098$). Both flours provided similar amounts of fiber and an antioxidant content close to 190 $\mu\text{mol Trolox equivalents} \cdot \text{g}^{-1}$. For these functionally relevant attributes, cultivar choice was immaterial: Hass and Fuerte offered comparable bioactive value, supporting their use as a stable source of antioxidant compounds.

Carbohydrates and crude protein followed a similar pattern, with no significant differences between Hass and Fuerte ($P>0.131$ and $P>0.100$, respectively). The crude-protein result, however, should be interpreted cautiously because, with only three replicates per group, the Mann-Whitney U test cannot yield a P value below 0.100, no matter how marked the difference between the observed means (3.13% for Hass versus 5.03% for Fuerte). Before concluding that the varieties provide equivalent protein

amounts, the determination should be repeated with a larger number of samples.

The findings confirm that avocado seeds, which are usually discarded, can be reintroduced into the food chain as flour. This transformation uses an abundant residue and recovers its fiber and antioxidant content. The choice between Hass and Fuerte may be based on availability, cost, or yield without affecting bioactive contribution. However, the number of replicates should be increased and other components analyzed before industrial applications are projected, thereby strengthening these conclusions.

Overall, the results support the potential of avocado seeds as raw materials for functional ingredients, contributing to agro-industrial waste valorization and circular-economy strategies. Future studies should nevertheless increase the number of experimental replicates, quantify total polyphenols, characterize the mineral profile, and employ complementary antioxidant methods to consolidate the prospects for food and nutraceutical use of these flours.

Conflict of Interest

The authors declare that they have no conflicts of interest at any stage of this publication.

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CRedit author contribution statement

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