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Differential Characteristics in the Chemical Composition of Bananas from Tenerife (Canary Islands) and Ecuador

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The contents of moisture, protein, ash, ascorbic acid, glucose, fructose, total sugars, and total and insoluble fiber were determined in cultivars of bananas (Gran Enana and Pequeña Enana) harvested in Tenerife and in bananas (Gran Enana) from Ecuador. The chemical compositions in the bananas from Tenerife and from Ecuador were clearly different. The cultivar did not influence the chemical composition, except for insoluble fiber content. Variations of the chemical composition were observed in the bananas from Tenerife according to cultivation method (greenhouse and outdoors), farming style (conventional and organic), and region of production (north and south). A highly significant ($r = 0.995$) correlation between glucose and fructose was observed. Correlations of ash and protein contents tend to separate the banana samples according to origin. A higher content of protein, ash, and ascorbic acid was observed as the length of the banana decreased. Applying factor analysis, the bananas from Ecuador were well separated from the bananas produced in Tenerife. An almost total differentiation (91.7%) between bananas from Tenerife and bananas from Ecuador was obtained by selecting protein, ash, and ascorbic acid content and applying stepwise discriminant analysis. By selecting the bananas Pequeña Enana and using discriminant analysis, a clear separation of the samples according to the region of production and farming style was observed.

KEYWORDS: Outdoors and greenhouse; farming style: organic and conventional; region of production: north and south; multivariate techniques

INTRODUCTION

Bananas and apples are the fruits with the highest consumption in the European market. The banana, which is an excellent tropical fruit, has an agreeable flavor and a high nutritional value. The contribution to the intake of sugars, fiber, vitamins, and minerals from the consumption of bananas is high, with a very low contribution to the intake of fat.

Approximately 70% of the total production of bananas in the world occurs in Latin America. Ecuador is the main producer of bananas, producing about 30% of all the bananas from Latin America. Banana production in Tenerife (Canary Islands) accounts for a large part of agricultural exports from these islands, representing ≅3.4% of the world trade in bananas. Approximately 20% of agricultural land in the Canary Islands is used for banana production. Tenerife is the island with the highest production, which represents a third of the total. About 35 000 people (4% of the total population) live from the farming of this tropical fruit (*1*).

The chemical composition and the nutritional value of the bananas can be influenced by many factors. As such, bananas produced in Tenerife have special characteristics which are due to several factors. (1) Cultivars for production: There are two important cultivars produced in the Canary Islands, "Gran Enana" and "Pequeña Enana", belonging to the species *Musa acuminata AAA* (variety Cavendish). (2) Climatic conditions: The climate in the Canary Islands is subtropical, with a mean annual temperature in coastal areas below the optimum temperature for the cultivation of bananas. There are different climatic conditions (humidity and temperature) in Tenerife as a consequence of an accentuated relief and wind direction which makes the regions in the north and south of the island very different. (3) Soil composition or arable land: Although the Canary Islands are volcanic by nature, the physicochemical characteristics of the soils for farming of bananas change as a function of the region considered. (4) Agricultural practices: There are many variables that influence the chemical composition of bananas, such as methods of cultivation, fertilizers and pesticides used, quality of water for irrigation, or storage and commercialization conditions (*2*).

Each year, the consumption of organically grown fruit is increasing. Organic bananas are produced (about 500 tons) according to the European regulations of ecological plantation (*3*), which regulates the use of fertilizers, antiparasitic products, and water and controls production and commercialization. Most organic plantations are less than one hectare in size. The main

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Table 1. Descriptions of the Banana Samples According to Farming Style, Cultivation Method, and Origin and Localization of Farms

		farming style		cultivation method		location of farms	
cultivar	*n*	conventional	organic	greenhouse	outdoors	south	north
banana from Tenerife	95	84	11	35	60	71	24
Gran Enana	36	36	0	18	18	36	0
Pequeña Enana	59	48	11	17	42 (31)[a]	35	24 (13)[a]
banana from Ecuador	16	16	0	0	16		

[a] Banana samples cultivated conventionally.

problems of organic agriculture are parasites and less effective fertilization. These problems increase costs, especially labor costs.

In a previous paper (*4*), we demonstrated that, by using the mineral contents, it is possible to differentiate bananas according to origin. In this study, we determined the chemical compounds (moisture, protein, ash, ascorbic acid, sucrose, glucose, fructose, and total and insoluble fiber) in bananas from Tenerife and bananas from Ecuador (South America). The influence of cultivation method (greenhouse or outdoors) and/or farming style (conventional or organic) on the chemical compounds was considered. A statistical study of correlation to find the relationships among the parameters studied was carried out. Multivariate techniques using factor and discriminant analysis were applied on all the data and on several groups of bananas in order to classify the banana samples into homogeneous groups.

MATERIALS AND METHODS

Samples. A total of 111 samples of bananas were analyzed, 95 cultivated in the island of Tenerife and 16 cultivated in Ecuador. The main characteristics of the banana samples are described in **Table 1**. The samples ($n = 59$) of Pequeña Enana were divided according to conventional ($n = 48$) and organic ($n = 11$) cultivation type. The samples from Tenerife were provided by COPLACA (Cooperativa de Plátanos de Canarias) from 43 different farms located in various regions of the island of Tenerife. The two cultivars (Gran Enana and Pequeña Enana) produced in the Canary Islands were analyzed. The sampling was carried out between March 2000 and March 2002. For obtaining the bananas samples, the second "layer" of the upper part of a banana bunch was collected. This second layer was cut when it was green (ripening color: point no. 1) with a minimum length of 13 cm and was ripened in the laboratory using "Ketefon" (Kenogakenogard, S.A., Barcelona, Spain), stored in chambers at room temperature. When the color of the bananas was "yellow" (ripening color: point no. 6) and the full flavor and adequate conditions for its consumption were observed, the diameter and length were determined. After ripening the bananas from each layer, three bananas were taken for analysis. The 16 samples from Ecuador were acquired on different days from MERCAMADRID between June and September 2001, presenting the same characteristics (ripening color: point no. 1) as the bananas from Tenerife, and they were ripened in the same way.

Analytical Methods. The analyses were repeated three times. In the cases of fiber and sugars they were carried out in duplicate. To determine the moisture and ash content, the bananas were cut into slices of approximately 2.5 g. About 40 g was dried for the analyses of total and insoluble fiber. About 20 g was dried for the protein determination. The samples for the sugar analyses were prepared by using a model T-25 Basic Turmix (Ika-Werke, Staufen, Germany) to homogeneously mix 3 g in 20 mL of ethanol (80%). Afterward, the tubes were centrifuged, and the liquid phase was stored at −18 °C in a freezer. The analysis of ascorbic acid was carried out independently of the fresh fruit. Three bananas were analyzed in duplicate subsamples for each layer.

Moisture was determined by desiccation at 105 °C for 24 h, according to the method described by the Association of Official Analytical Chemists (AOAC) (*5*). Ash was determined by ashing the residue of moisture determination at 550 °C for 24 h. Nitrogen content was obtained by applying the Kjeldahl method (*5*), and the protein content was calculated by using a nitrogen factor of 6.25. Dietary and insoluble fiber was determined according to the methods proposed by Prosky et al. (*6*, *7*). Ascorbic acid was determined by the dichlorophenol−indophenol titration procedure (*5*). Ascorbic acid was extracted by using a solution containing 8% (v/v) acetic acid and 3% (w/v) metaphosphoric acid.

Sugar analysis was performed on a Waters HPLC chromatograph equipped with a refractive index detector (2410) and a 300- × 6.5-mm Sugar Pak column (Waters, MA). An aliquot of ethanolic extract was passed through a 0.45-μL filter (Millipore, Bedford, MA), and 1 mL of the filtration solution was passed through a Sep-Pak cartridge (Waters), which was previously activated with 5 mL of methanol and 5 mL of ultrapure water. The cartridge was then washed with 5 mL of Milli-Q water. Glucose, fructose, and sucrose concentrations were determined by injecting 20 μL of the standard solutions or sample extracts and eluting with the mobile phase [50 mg of calcium-Titriplex dihydrate (Merck, Germany) in 1 L of ultrapure water] at a flow rate of 0.5 mL/min. The temperature of the column was maintained at 90 °C (*8*). The HPLC peaks were identified by comparing the retention times with those of commercial standards of the sugars sucrose, glucose, and fructose (Sigma, Madrid, Spain).

Methods for the determination of protein, ash, and soluble and insoluble fiber were validated with Certified Reference Material (Rye CRM-381, LGC Deselaers S.L., Barcelona, Spain). The percent of recovery ranged from 97.5% to 101.5%. The percent standard deviation ranged from 0.68% to 5.62%. Analytical methods such as HPLC of sugars and titration of ascorbic acid had quality control samples, which were spiked and checked with commercial standards provided by Sigma. Spike recoveries and check standards for HPLC methods were typically within ±10% of their true value, and standard deviations were 5% for the rest.

Statistics. All statistical analyses have been performed by means of the SPSS version 10.0 software for Windows. The Kolmogorow−Smirnov−Lilliefors test was applied to verify if the variable had a normal distribution, $p < 0.05$. The mean values obtained in the different groups were compared by one-way ANOVA and *t*-test, assuming that there were significant differences between mean values when statistical comparison gave $p < 0.05$. Simple linear and logarithmic correlation analysis was used to indicate a measure of the correlation and the strength of the relationship between two variables. Factor analysis, using principal components as the method for extraction of factors, was used to summarize the information in a reduced number of factors, and linear discriminant analysis was used to select the most useful variables in the differentiation among aggregations.

RESULTS AND DISCUSSION

Figure 1 shows the mean concentrations of the chemical components analyzed and mean values of length and diameter for the 18 samples of Gran Enana from Tenerife harvested outdoors and 16 counterparts imported from Ecuador. Important differences were observed between the mean contents for most of the chemical compounds analyzed. Bananas from Tenerife had higher mean contents of protein ($p = 0.000$), ash ($p = 0.000$), ascorbic acid ($p = 0.024$), glucose ($p = 0.038$), fructose ($p = 0.024$), and total sugars ($p = 0.018$), and the bananas from

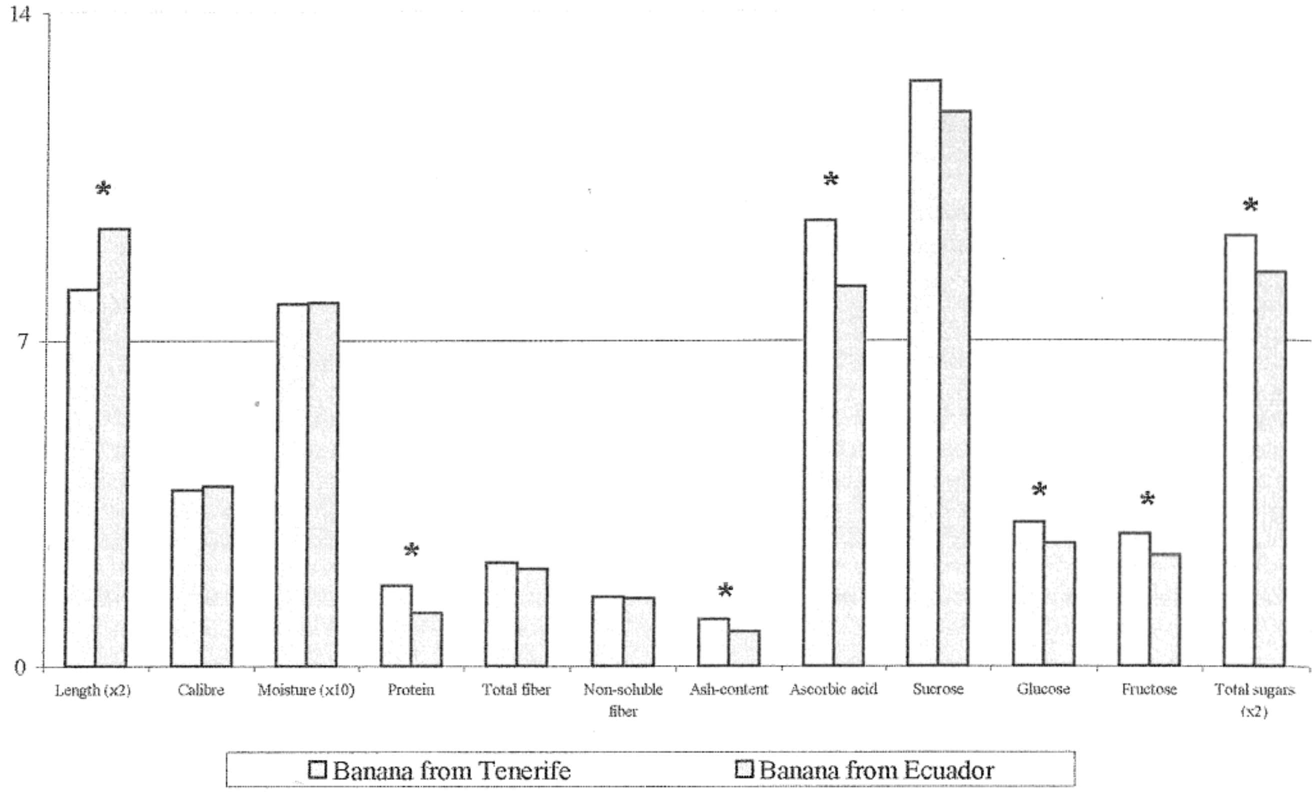

Figure 1. Comparison of the chemical composition between bananas from Tenerife and from Ecuador (asterisk indicates significant differences between mean values). All data are expressed in grams per 100 g, except for ascorbic acid (milligrams per 100 g), length (centimeters), and diameter (centimeters).

Ecuador were longer ($p = 0.013$). The ratio among the sugars analyzed presented slight differences according to the origin of the bananas. Bananas from Tenerife had a ratio of 64:19:17 for sucrose, glucose, and fructose, respectively, whereas bananas from Ecuador showed the ratio of 70:16:14. These ratios are similar to the data described in the literature (65:20:15) (*9*). The mean values for the rest of the parameters analyzed did not present significant differences between the bananas from Tenerife and those from Ecuador. The bananas from Tenerife showed clear differences in chemical composition in relation to the bananas from Ecuador. Therefore, an important influence on the chemical composition of the bananas of the region of production and/or agricultural practices can be deduced. These important differences agree with the fact that the bananas from Tenerife known as "*Plátano canario*" are a different product in relation to other bananas produced in other regions of the world (*2*). Bananas from Tenerife had very specific characteristics, such as being smaller, having a sweeter taste, and being softer than bananas from Ecuador.

These results confirm the importance of the recommendations indicated by The United Nations Organization for Food and Agriculture (FAO) about the preparation of Food Composition Charts of food produced and consumed locally. The moisture of the bananas analyzed here had values of about 75%, in agreement with other published data (*10*−*13*).The sugars are the main components of the dry extract, representing about 75% of the total. The contents of sucrose, glucose, and fructose were within the same range of values described for bananas from Venezuela (*11*) and data included in Food Composition Charts (*12*, *13*). The concentration of protein in bananas from Tenerife was slightly higher than the data reported for bananas in Food Composition Charts (*12*, *13*) but similar to data reported for bananas produced in Venezuela (*11*). The fiber and ash contents in bananas produced in Tenerife were higher than data published for other regions and included in some Food Composition Charts (*12*, *13*). The results for ascorbic acid were much higher than some data reported for bananas from Venezuela (*11*) or from the United States (*10*); however, they are similar to the data described in the Food Composition Charts (*12*, *13*).

Table 2. Contribution to Daily Dietary Intake of Nutrients of the Adult Population for the Consumption of 100 g of Canary Banana (Pequeña Enana, Gran Enana) and Banana from Ecuador

		Tenerife banana				banana from Ecuador	
		Pequeña Enana		Gran Enana		Gran Enana	
nutrient	RDI[a] (g/day)	intake (g/100 g)	% of RDI	intake '(g/100 g)	% of RDI	intake (g/100 g)	% of RDI
protein	54 (41)[b]	1.51	2.8 (3.7)	1.61	3.0 (3.9)	1.15	2.1 (2.8)
total fiber	>25	2.41	9.6	2.34	9.4	2.10	8.4
ascorbic acid	0.060	0.011	17.7	0.010	16.2	0.008	13.5

[a] Recommended dietary intake for Spanish adult population. [b] The values for women are indicated in parentheses.

The mean consumption of bananas in the Canary Islands population is estimated at 25 g per person per day, but there is a large segment (≈25%) of consumers who consume nearly 100 g per day (edible portion of a medium-sized banana of 150 g) (*14*). **Table 2** shows the contribution to the dietary daily intake of protein, fiber, and ascorbic acid by the consumption of one medium-sized banana in relation to the recommended dietary intakes (RDI) for the Spanish population (*15*). Compared with other foods, such as fruits and vegetables, the contribution to protein intake was considerable (2−3% and 4.5% of the RDI for men and women, respectively). The contribution to the intake of fiber was high, representing approximately 9.5% and 8.4% of the minimum recommended when the bananas from Tenerife and Ecuador were consumed, respectively. The consumption of bananas contributes significantly to the intake of ascorbic

Table 3. Chemical Composition in Bananas from Tenerife According to Cultivar, Cultivation Method, and Farming Style

cultivar	*n*	length (cm)	diameter (cm)	moisture (%)	protein (%)	total fiber (%)	insoluble fiber (%)	ash content (%)	ascorbic acid (mg/100 g)	sucrose (%)	glucose (%)	fructose (%)	total sugars (%)
(A) Pequeña Enana													
total[a]	48	15.88 ± 0.87[b]	3.86 ± 0.18	77.75 ± 1.98	1.56 ± 0.26	2.45 ± 0.51	1.38 ± 0.18	1.00 ± 0.08	10.16 ± 2.10	11.27 ± 3.11	3.45 ± 0.81	3.16 ± 0.74	17.90 ± 3.22
greenhouse	17	16.52 ± 0.75	3.90 ± 0.15	77.69 ± 1.58	1.56 ± 0.18	2.35 ± 0.40	1.40 ± 0.15	1.00 ± 0.08	9.88 ± 1.57	10.97 ± 4.34	2.96 ± 0.43	2.69 ± 0.40	16.68 ± 4.61
outdoors													
conventional	31	15.60 ± 0.79	3.84 ± 0.20	77.78 ± 2.19	1.55 ± 0.30	2.37 ± 0.50	1.42 ± 0.23	1.01 ± 0.07	10.32 ± 2.35	11.43 ± 2.24	3.72 ± 0.85	3.41 ± 0.77	18.57 ± 1.91
organic	11	13.61 ± 0.89	3.63 ± 0.32	75.34 ± 2.24	1.30 ± 0.29	2.63 ± 0.39	1.57 ± 0.23	1.05 ± 0.12	12.60 ± 2.39	11.80 ± 1.84	2.97 ± 0.92	2.77 ± 0.82	17.53 ± 2.24
(B) Gran Enana													
total	36	16.44 ± 1.26	3.77 ± 0.17	77.45 ± 2.28	1.61 ± 0.30	2.34 ± 0.55	1.50 ± 0.24	0.97 ± 0.12	9.69 ± 1.50	10.84 ± 2.52	3.13 ± 0.75	2.86 ± 0.68	16.83 ± 2.79
outdoors	18	16.17 ± 0.71	3.79 ± 0.13	77.73 ± 1.97	1.74 ± 0.32	2.23 ± 0.55	1.49 ± 0.24	1.01 ± 0.14	9.56 ± 1.69	12.51 ± 2.26	3.10 ± 0.75	2.84 ± 0.68	18.45 ± 2.25
greenhouse	18	16.67 ± 1.61	3.76 ± 0.20	77.17 ± 2.58	1.48 ± 0.21	2.45 ± 0.54	1.50 ± 0.24	0.93 ± 0.08	9.83 ± 1.32	9.18 ± 1.45	3.15 ± 0.77	2.88 ± 0.70	15.20 ± 2.33

[a] Organic samples not included. [b] Mean ± deviation standard.

acid, accounting for between 13.5% and 17.7% of the RDI, depending on the cultivar and provenance of banana. Therefore, if the consumption of bananas increases, the daily intake of fiber and ascorbic acid would increase.

Table 3 shows the results relative to length and diameter and the chemical compound contents (moisture, protein, total and insoluble fiber, ash, ascorbic acid, sucrose, glucose, fructose, and total sugars) for both cultivars of bananas from Tenerife, Gran Enana (GE) and Pequeña Enana (PE), cultivated in greenhouses and outdoors. The results of conventional and organic alternatives were also included. The chemical compound contents for both cultivars of bananas were fairly similar. This agrees with the results reported by Galán and Cabrera (*16*), who did not find any important differences in the sensorial quality between the cultivars Gran Enana and Pequeña Enana harvested in the Canary Islands. The genetic characteristics of the Cavendish variety and the similar conditions of cultivation and ripening could explain these similar results (*2*, *16*). No significant differences were observed for all the chemical compounds, except for insoluble fiber, of which the Gran Enana cultivar was found to have a higher ($p = 0.014$) mean concentration. However, Pequeña Enana cultivar tends to have higher contents for sugars, ascorbic acid, and ash contents. There are probably other factors, such as the cultivation method or farming style, nature of the soil, or climatic conditions, that have a greater effect than the type of cultivar.

The outdoor banana samples of the Gran Enana cultivar presented higher mean contents of protein ($p = 0.050$), ash ($p = 0.005$), sucrose ($p = 0.000$), and total sugars ($p = 0.000$) than greenhouse bananas. On the other hand, the outdoor banana samples of the Pequeña Enana cultivar were shorter ($p = 0.026$) and had a higher mean content of glucose ($p = 0.001$), fructose ($p = 0.001$), and total sugars ($p = 0.050$) than the greenhouse samples. Some interesting differences were found when the outdoor samples of Pequeña Enana cultivated in a conventional way were compared according to the region (north or south) of the island. The northern bananas presented a higher mean content of moisture ($p = 0.004$), total fiber ($p = 0.010$), glucose ($p = 0.000$), and fructose ($p = 0.000$) and a lower mean content of sucrose ($p = 0.004$) than the southern bananas. The cultivation style (conventional or organic) in the samples of outdoor Pequeña Enana had an interesting influence on the chemical composition of the bananas and, consequently, on their nutritional value. Organic bananas were shorter ($p = 0.001$) and had a lower mean content of moisture ($p = 0.000$) and monosaccharides such as glucose ($p = 0.000$) and fructose ($p = 0.000$). In contrast, the organic bananas presented higher mean concentrations of sucrose ($p = 0.044$) and ascorbic acid ($p = 0.019$). In addition, the conventional bananas had more protein and less ash than the organic ones, although in these cases no significant differences were found. These differences could be attributed to the use of different types of fertilizers which influence the chemical composition.

The correlation matrix (**Table 4**) shows the presence of a high number of significant ($p < 0.05$) correlations between the chemical compounds for all the data. The highly significant correlation ($r = 0.995$) between both monosaccharides, glucose and fructose, may be emphasized. This could be related to the common origin and metabolism of both sugars. This correlation defines the following regression line that allows the determination of the content of one sugar when the other is known:

$$[\text{fructose (g/100 g)}] = 0.905[\text{glucose (g/100 g)}] - 0.044$$

Significant correlations were obviously observed between the total sugars and sucrose, fructose, and glucose. Moisture showed many significant correlations, emphasizing the positive correlation with the sugars and negative correlation with the ash and insoluble fiber. Ash showed an interesting correlation with the protein and ascorbic acid. These correlations were also observed when the Gran Enana bananas were selected; however, they were not significant in the Pequeña Enana samples. The ash–protein correlation suggests that the minerals in bananas are mainly associated with the protein fraction. In **Figure 2A**, the graphic representation of this correlation is shown, and one can observe that the bananas from Ecuador are differentiated from the bananas from Tenerife. Moderate correlations between protein and glucose and fructose were observed, and these correlations improved when the Gran Enana bananas were selected. The two fractions of fiber analyzed were correlated in all the banana samples and when both cultivars were studied independently. Total fiber correlated positively with ascorbic acid and negatively with sucrose and total sugars. These correlations were repeated when both of the cultivars were considered independently. The negative correlation between fiber and soluble sugars has been described by other authors (*17*). The length presented negative correlation with the protein, ash, and ascorbic acid, emphasizing the protein–length correlation (**Figure 2B**). A higher content of these chemical compounds was observed as the length of the bananas decreased, and the bananas tended to separate according to origin.

Table 4. Matrix Correlation of the Analyzed Parameters for All the Samples (n = 111)

	diameter	moisture	protein	total fiber	insoluble fiber	ash content	ascorbic acid	sucrose	glucose	fructose	total sugars
length[a]	**0.546**[b] **(0.000)**[c]	−0.013 (0.924)	−0.291 (0.033)	−0.185 (0.181)	−0.026 (0.853)	**−0.455 (0.000)**	**−0.351 (0.008)**	−0.019 (0.888)	−0.102 (0.456)	−0.113 (0.407)	−0.091 (0.506)
diameter[a]		−0.056 (0.680)	0.011 (0.935)	−0.181 (0.190)	−0.218 (0.116)	−0.008 (0.951)	−0.065 (0.634)	−0.001 (0.995)	0.126 (0.357)	0.107 (0.431)	0.079 (0.561)
moisture			0.097 (0.314)	−0.176 (0.067)	**−0.272 (0.005)**	−0.234 (0.014)	−0.200 (0.035)	−0.212 (0.025)	**0.311 (0.001)**	**0.303 (0.001)**	−0.026 (0.788)
protein				0.155 (0.107)	−0.091 (0.357)	**0.305 (0.001)**	0.076 (0.433)	−0.090 (0.350)	0.218 (0.023)	0.220 (0.021)	0.038 (0.693)
total fiber					**0.517 (0.000)**	0.240 (0.012)	**0.403 (0.000)**	**−0.350 (0.000)**	0.081 (0.402)	0.094 (0.333)	**−0.276 (0.004)**
insoluble fiber						0.097 (0.324)	0.166 (0.091)	−0.016 (0.869)	−0.066 (0.501)	−0.079 (0.423)	−0.059 (0.547)
ash content							**0.289 (0.002)**	0.105 (0.271)	0.197 (0.038)	0.216 (0.023)	0.210 (0.027)
ascorbic acid								−0.046 (0.634)	−0.032 (0.741)	−0.009 (0.925)	−0.054 (0.576)
sucrose									−0.152 (0.111)	−0.167 (0.079)	**0.842 (0.000)**
glucose										**0.995 (0.000)**	**0.403 (0.000)**
fructose											**0.389 (0.000)**

[a] n = 56. [b] Pearson correlation coefficient. [c] Signification level.

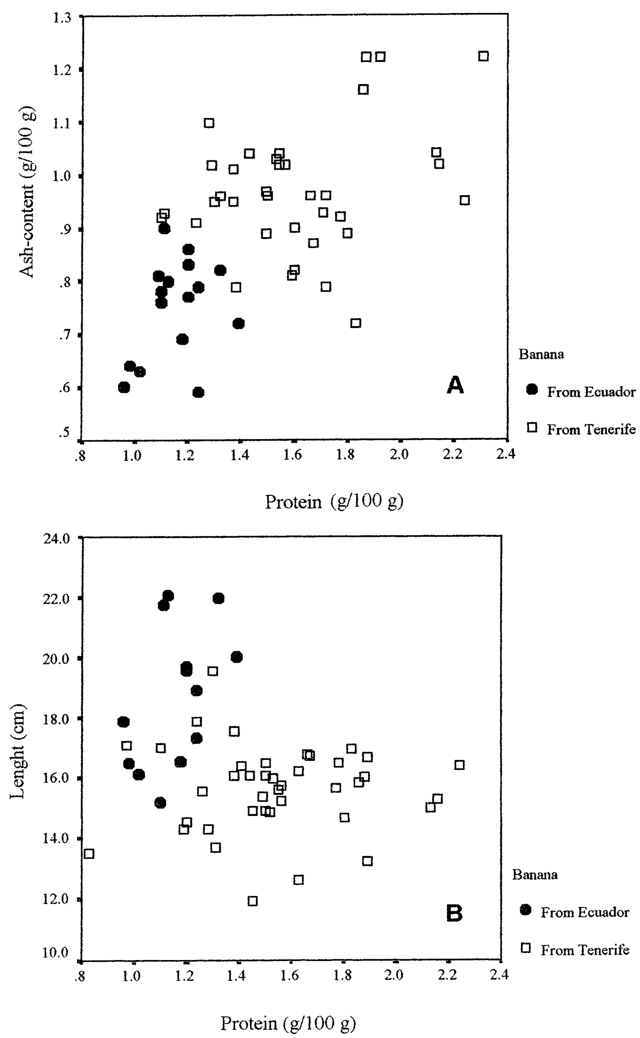

Figure 2. Plot of correlation between ash and protein (A) and length and protein (B), differentiating the origin of bananas.

Factor analysis, using the principal components method for the extraction of factors, was applied to all the samples of bananas studied to obtain a more simplified view of the relationship among the chemical compounds analyzed. Four factors were chosen (75.9% of the total variance) because their eigenvalues were higher than 1, and therefore, they explain more variance than the original variables. A Varimax rotation was carried out to minimize the number of variables that influence each factor and thus facilitate the interpretation of the results (**Table 5**). The first factor that explains the higher percentage of variance (26.8%) is strongly associated with the monosaccharides, glucose and fructose. The second factor is related to total and insoluble fiber, and the third factor is associated with protein and, to a lesser extent, with ash. Sucrose had a substantial weight in the fourth factor. Representing the score plots for all the banana samples on the first and third factors (**Figure 3**), it can be observed that the bananas from Ecuador tend to separate graphically from the bananas produced in Tenerife. No separation was observed between the Gran Enana and Pequeña Enana cultivars of the bananas from Tenerife.

Table 5. Factor Matrix Obtained after a Varimax Rotation

	Factor 1	Factor 2	Factor 3	Factor 4
% of total variance	26.8	23.3	14.4	11.5
moisture	0.341	−0.438	−0.118	−0.550
ash content	0.221	0.249	0.691	0.398
protein	0.120	−0.132	**0.786**	−0.243
ascorbic acid	−0.116	0.505	0.429	0.025
total fiber	0.059	**0.826**	0.213	−0.308
insoluble fiber	0.008	0.812	−0.220	0.098
sucrose	−0.067	−0.226	−0.093	**0.857**
glucose	**0.982**	−0.016	0.096	−0.084
fructose	0.978	−0.009	0.119	−0.088

Discriminant analysis (DA) is based on the extraction of linear discriminant functions of the independent variables by means of a qualitative dependent variable and several quantitative independent variables. Two processes can be applied in DA: (1) stepwise DA that selects the quantitative variables that enhance discrimination of the groups established by the dependent variable, and (2) introduction of all independent variables. The objective of this process is not to lose information, although the system obtained is more complex.

In this investigation, we have performed various studies of DA, each one considering different qualitative variables (origin,

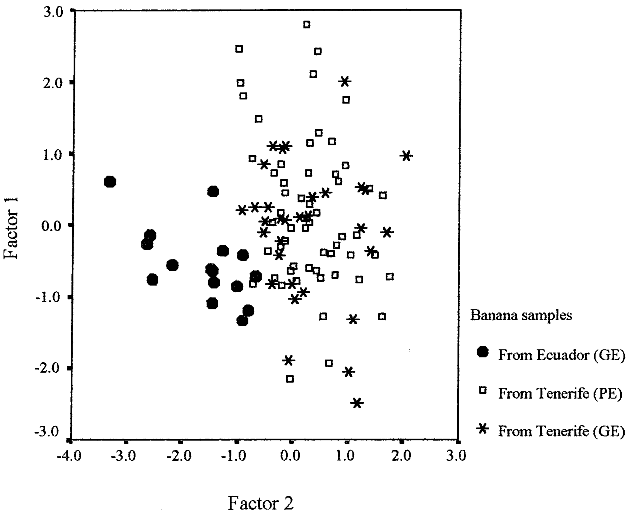

Figure 3. Scores of the banana samples on axes representing Factor 1 and Factor 3, differentiating Gran Enana (from Ecuador and Tenerife) and Pequeña Enana (from Tenerife).

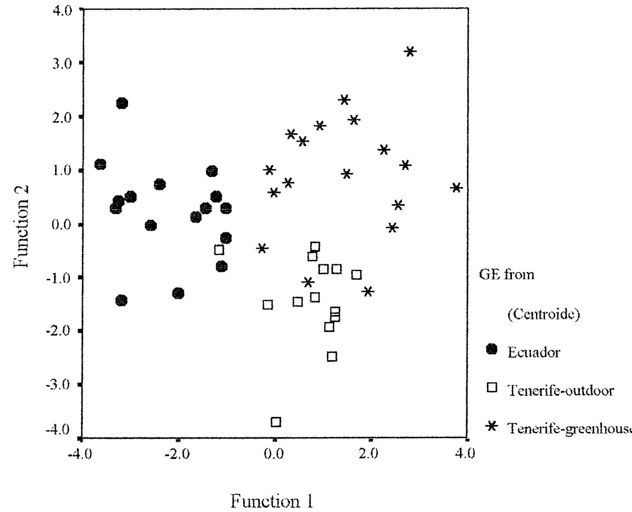

Figure 4. Scatter diagram of the Gran Enana banana samples on the axes representing the first two-function discriminant differentiating bananas from Ecuador and from Tenerife (outdoor and greenhouse).

Table 6. Results of the Discriminant Analysis According to Origin of Bananas

	banana	all variables predicted group: from Tenerife	all variables predicted group: from Ecuador	stepwise predicted group: from Tenerife	stepwise predicted group: from Ecuador
initial group	from Tenerife	87 (97.8%)	2 (2.2%)	84 (90.3%)	9 (9.7%)
	from Ecuador	0 (0.0%)	16 (100.0%)	0 (0.0%)	16 (100.0%)
cross-validation	from Tenerife	85 (95.5%)	4 (4.5%)	83 (89.2%)	10 (10.8%)
	from Ecuador	1 (6.3%)	15 (93.8%)	0 (0.0%)	16 (100.0%)
		98.1% samples well classified (95.2% after cross-validation)		91.7% samples well classified (90.8% after cross-validation)	

cultivars, cultivation method, farming style, and production region) and nine quantitative variables (moisture, ash, protein, total and insoluble fiber, ascorbic acid, sucrose, glucose, and fructose). Considering the origin criterion (bananas from Tenerife vs bananas from Ecuador), and after application of the stepwise DA to the data (**Table 6**), a high percentage (91.7% and 90.8% after cross-validation) of correct classification was obtained. All the bananas from Ecuador were correctly classified, and only nine bananas from Tenerife were erroneously included in the group of bananas from Ecuador. Three quantitative variables were selected: protein, ash, and ascorbic acid. One discriminant function was extracted, which is a linear combination of these quantitative variables. This function presented an eigenvalue of 1.251 and a coefficient of canonical correlation of 0.745. When the DA was applied to all the variables, the classification improved to 98.1% (with a cross-validation of 95.2%) (**Table 6**). All bananas from Ecuador were correctly classified, and it can therefore be deduced that the bananas from Ecuador had a chemical composition that makes it possible to differentiate them from the bananas from Tenerife.

A subsequent analysis on several groups of bananas from Tenerife was carried out using the cultivars as criteria for comparison. The correct classifications with stepwise DA were low (72.2% and 67.1% after cross-validation). These percentages did not improve when all the quantitative variables were included (73.4% and 63.3% after cross-validation). Therefore, the samples of both cultivars of bananas produced in Tenerife presented a relatively homogeneous chemical composition. A stepwise DA was applied to the Gran Enana cultivar in order to distinguish the bananas from Ecuador, the bananas from Tenerife cultivated outdoors, and the bananas from Tenerife cultivated in the greenhouse (**Table 7**) (88.5% and 86.5% after cross-validation). Stepwise DA selected three variables (protein, sucrose, and ash); all the bananas from Ecuador and 83.3% of the Gran Enana bananas from Tenerife (outdoors and greenhouses) were correctly classified. The two discriminant functions are represented in **Figure 4**, and one can observe that the bananas from Ecuador are well separated. Also, the bananas from Tenerife tend to differentiate on the basis of the cultivation method. These percentages slightly improve when all the quantitative variables are included (91.7% and 79.2% after cross-validation).

Similarly, a DA (stepwise and all the variables) was carried out on the Pequeña Enana bananas to differentiate them by cultivation method and farming style. When the stepwise DA

Table 7. Results of the Discriminant Analysis Performed with Gran Enana Bananas According to Cultivation Method and Origin of Bananas

	banana	all variables predicted group: outdoor from Tenerife	all variables predicted group: greenhouse from Tenerife	all variables predicted group: banana from Ecuador	stepwise predicted group: outdoor from Tenerife	stepwise predicted group: greenhouse from Tenerife	stepwise predicted group: banana from Ecuador
initial group	outdoor from Tenerife	15 (83.3%)	3 (16.7%)	0 (0.0%)	15 (83.3%)	3 (16.7%)	0 (0.0%)
	greenhouse from Tenerife	0 (0.0%)	13 (92.9%)	1 (7.1%)	2 (11.1%)	15 (83.3%)	1 (5.6%)
	banana from Ecuador	0 (0.0%)	0 (0.0%)	16 (100.0%	0 (0.0%)	0 (0.0%)	16 (100.0%)
cross-validation	outdoor from Tenerife	14 (77.8%)	4 (22.2%)	0 (0.0%)	15 (83.3%)	3 (16.7%)	0 (0.0%)
	greenhouse from Tenerife	4 (28.6%)	9 (64.3%)	1 (7.1%)	3 (16.7%)	14 (77.8%)	1 (5.6%)
	banana from Ecuador	0 (0.0%)	1 (6.3%)	15 (93.8%)	0 (0.0%)	0 (0.0%)	16 (100.0%)
			91.7% samples well classified (79.2% after cross-validation)			88.5% samples well classified (86.5% after cross-validation)	

Table 8. Results of the Discriminant Analysis According to the Region of Production

	Pequeña Enana	all variables predicted group		stepwise predicted group	
		from north	from south	from north	from south
initial group	from north	11 (91.7%)	1 (8.3%)	11 (91.7%)	1 (8.3%)
	from south	1 (2.9%)	34 (97.1%)	1 (2.9%)	34 (97.1%)
cross-validation	from north	11 (91.7%)	1 (8.3%)	11 (91.7%)	1 (8.3%)
	from south	1 (2.9%)	34 (97.1%)	1 (2.9%)	34 (97.1%)
		95.7% samples well classified (95.7% after cross-validation)		95.7% samples well classified (95.7% after cross-validation)	

was applied, the variables selected were fructose, moisture, ascorbic acid, and glucose. The correct classification of the samples was low (64.4% and 52.5% after cross-validation) and improved when all the variables were included to 70.2% (64.9% with cross-validation). Thus, considering the chemical compounds determined, the Pequeña Enana bananas analyzed here are relatively homogeneous, which does not allow their satisfactory classification on the basis of the farming style or cultivation method. However, a new DA study was developed considering the conventional Pequeña Enana bananas and using the region (north or south) of production as a criterion for comparison (**Table 8**). Using the stepwise process, the ash, protein, insoluble fiber, and fructose variables were selected, and an almost complete differentiation of the samples was obtained (95.7% and 95.7% after cross-validation). Only one sample of northern banana was erroneously classified in the group corresponding to the southern and vice versa. The outdoor Pequeña Enana bananas produced in the northern part of the island were selected for the application of a DA to distinguish organic and conventional cultivation (**Table 8**). By applying stepwise DA, only two variables (moisture and total fiber) were selected, and 86.4% of the bananas (86.4% with cross-validation) were correctly classified. An almost completely correct classification was obtained when all the variables were introduced (95.5% and 95.5% after cross-validation). Only one conventional banana was erroneously considered as being an organic banana.

Clear differences in the chemical composition were observed between the bananas harvested in Tenerife and Ecuador. No important differences in the chemical composition were found between the cultivars of bananas produced in Tenerife. The outdoor bananas had a higher mean content of total sugars than the greenhouse samples. Pequeña Enana from the north presented higher moisture, total fiber, glucose, and fructose contents and lower sucrose content than those from the south. Organic bananas had higher sucrose and ascorbic acid contents and lower moisture, glucose, and fructose contents than the corresponding conventional bananas. Many correlations between the chemical compounds were found, emphasizing the highly significant correlation between glucose and fructose. The multivariate analysis is useful for the determination of the provenance, farming style, and cultivation method of the banana samples. The determination of protein, ash, and ascorbic acid contents enables one to differentiate the bananas produced in Tenerife from the bananas from Ecuador.

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