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Differences among Spanish and Latin-American banana cultivars: morphological, chemical and sensory characteristics

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Physical (weight, size, shape, texture and colour), physicochemical (pH, titratable acidity, soluble solids, moisture content, total solids), chemical (soluble sugars, vitamin C, starch, pectic substances, volatile compounds) and biochemical (polyphenol oxidase and peroxidase activities, soluble proteins) characteristics and sensory attributes (appearance, flavour, odour, colour, firmness, acceptability) of banana (*Musa cavendishii* L.) fruits were studied in order to assess possible differences between nutritional properties and consumer acceptability of the local (Canarian) cultivars Enana and Gran Enana and the Latin-American (Colombian) Enana cultivar. Significant differences ($P \leq 0.05$) were found between size and length of fruit, and between other objective measurements (lightness, yellowness, acidity, moisture content, starch, peroxidase and polyphenol oxidase activities, soluble sugars—sucrose, fructose, glucose). Also there were significant differences in vitamin C and protein content which established the higher nutritional value of the Spanish banana cultivars. The main compositional differences between the banana cultivars in terms of flavour were quantified. Purge and trap (head-space) analysis of the Spanish Enana cultivar showed it was the richest in the characteristic banana volatile aroma compounds. Sensory descriptive analysis discriminated between banana cultivars in terms of flesh colour and flesh sweetness; although panellists liked all cultivars, they preferred the Spanish Enana fruits (overall acceptability test). © 1997 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Banana is a commercially important fruit crop in world trade. For export, bananas must be harvested and shipped unripened. The ripe banana pulp contains mainly carbohydrates and supplies a good amount of energy (100 cal per 100 g). The banana is a fairly good source of vitamins A, B_1, B_2 and C.

The banana belongs to the genus *Musa* of the family Musaceae. Most edible bananas and plantains are descended from a wild ancestor, *Musa acuminata* and *Musa balbisiana*. The diploids (AA, AB), triploids (AAB, ABB), or tetraploids (AAAA, ABBB) arising from the genomes of these two genera give rise to various types of edible bananas and plantains (Salunke, 1984). Recently, a cultivar name preceded by the genus name and a group indication has been recommended: e.g. *Musa* (AAA group, Cavendish subgroup) (Samson, 1980).

The banana fruit is a berry containing many ovules, but no seeds, and the fruit develops by means of parthenocarpy (without fertilization). Cultivars differ in characteristics such as shape, size, colour of peel and flavour. Simmons (1966) and Samson (1980) have described major banana cultivars grown all over the world. The triploid genome groups such as AAA, AAB and ABB are the most important among commercially grown bananas. The banana is a widely consumed fruit. By volume, it is second only to milk in direct consumption, and in 1974 it was in seventh place among the commodities exported by developing nations. In countries such as Costa Rica and Honduras, bananas represent more than 25% of total exports. Central America

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exports around 5·9 million tons of bananas per year, but also generates over 1 million tons of reject fruit (Garcia *et al.*, 1985).

In Spain, bananas are harvested in tropical areas, mainly in the Canary Islands, where they are the most important commercial crop. Spanish banana fruits were protected for export in the European Union until 1994. After that date an important increase in Latin-American and African banana exports to Europe occurred and competition between Spanish and foreign banana fruits for the market began.

The purpose of this study was to evaluate the characteristics of the Spanish varieties normally commercialized in Spain, but also destined for export, and to compare their quality parameters with one of the most widespread Latin-American cultivars of banana distributed all over the world and recently introduced into Spain.

MATERIALS AND METHODS

Raw material

Banana fruits (*Musa cavendishii* L.) of the Gran Enana and Enana cultivars from the Canary Islands and the Enana cultivar from Colombia were obtained from commercial sources. Fruits were stored at 14 ± 1°C and 85–90% relative humidity (Salunke, 1984) until analysis (yellow–green peel colour, 70:30).

Fruits were selected at random, hand-peeled, sliced and cut into small pieces before analysis. All analyses, including sensory studies, were done immediately after slicing, in triplicate.

Physical determinations

Texture

Texture evaluation was carried out by the Kramer shear test in an Instron 1140 texturometer. Fifty grams of sectioned slices (0·8 cm thick) were laid in the Kramer cell. A force of 100 kg was applied at a crosshead speed of 50 mm min^{-1} and a chart speed of 100 mm min^{-1}. The mean value for maximum force was calculated. The results were reported as resistance to shear in N g^{-1} fresh weight (FW).

Colour

Colour was measured in each slice with a Hunterlab D25 A-9 Tristimulus Colorimeter. A standard white plate (No. c2-19952), having reflectance values of $X = 82{\cdot}51$, $Y = 84{\cdot}53$, $Z = 101{\cdot}23$, was used as reference. Banana slices were placed on the light port using a 5 cm diameter plastic dish with cover. Each value represents a mean of triplicate determinations of three different samples. Results were reported, as an average of individual values, as L (lightness), aL ($+a$ is red, $-a$ is green) and bL ($+b$ is yellow, $-b$ is blue).

Physicochemical determinations

pH

Ten grams of banana pulp were minced and blended with 40 ml of deionized water in a Sorvall Omnimixer. The pH was measured at this temperature with a Crison pH-meter.

Titratable acidity

After determination of the pH, the solution was titrated with 0·1 N NaOH up to pH 8·1. The results were expressed as percentage citric acid (g citric acid per 100 g FW) (AOAC, 1990).

Soluble solids

Soluble solids were measured in the exudate from the Kramer shear cell with an Atago digital refractometer dbx-30 at 20°C. Results were reported as degrees Brix.

Chemical determinations

Soluble sugars

The most important soluble carbohydrates in banana (sucrose, fructose and glucose) were analysed by high-performance liquid chromatography (Mollá *et al.*, 1994) using a Waters Associates modular instrument equipped with a 6000A pump, U6K injector and differential refractometer R401, and employing a μ-Bondapak/carbohydrate analysis column of stainless steel (Waters Millipore Associates). The eluent was a mixture of acetonitrile/water (80:20, v/v) working at room temperature and a flow rate of 0·9 ml min^{-1}. Sample preparation was carried out by homogenization of 5 g of minced banana pulp with 40 ml of methanol in a Sorvall Omnimixer at 2°C. The homogenate was centrifuged for 30 min at 3000*g* and the supernatants were collected. The mixture was cooled and filtered through Whatman No. 1 filter paper and the residue was washed twice with methanol. The filtrate was evaporated under vacuum at 50°C in a Büchi rotavapor. The residue was redissolved in 50 ml of distilled water. Then the samples were filtered through a Sep-Pak C18 cartridge (Waters Millipore Associates) and 2 ml of the filtrate were mixed with 8 ml of acetonitrile. Before injection, this solution was filtered through a 0·45 μm Millipore filter. The injection volume was 25 μl.

Starch

Starch content of banana pulp was analysed by a modification of the AOAC (1990) Method No. 22.087. This modification consisted of the use of enzymic hydrolysis of starch by amyloglucosidase (glucoamylase, 1,4-α-glucan glucohydrolase, EC 3.2.1.3; EU 10 000 units g^{-1}; Sigma) in 0·25 M sodium acetate buffer (pH 4·5) for 1 h at 55°C.

Pectic substances

Determination of total pectic substances was carried out by colorimetric analysis of galacturonic acid produced by alkaline hydrolysis of pectic compounds (Dische, 1947).

Vitamin C

Vitamin C was analysed using a fluorimetric method by formation of quinoxaline (Brubacher, 1985). A 25 g portion of homogenized fruit was diluted with 50 ml of metaphosphoric acid solution (80 g of metaphosphoric acid and 30 ml of glacial acetic acid made up to 100 ml with deionized water), allowed to stand for 15 min, made up to 100 ml, and then filtered. A 25 ml volume of the filtered homogenate was diluted to 50 ml with metaphosphoric acid solution. Then the ascorbic acid was oxidized to dehydroascorbic acid by 2 g of activated carbon. The mixture was allowed to stand for 30 min and filtered. The sample solution was made with 5 ml of sample filtrate diluted with 5 ml of sodium acetate solution (500 g of sodium acetate trihydrate dissolved in 1 litre of deionized water), and after standing for 15 min the solution was made up to 50 ml with deionized water.

A 2 ml volume of each sample solution was diluted with 5 ml of 1,2-phenylenediamine solution (40 mg of 1,2-phenylenediamine dissolved in 100 ml of deionized water) and allowed to stand for 35 min in the dark. A sample solution blank was made with 5 ml of sample filtrate with 5 ml of boric acid/sodium acetate solution (3 g of boric acid dissolved in 100 ml of sodium acetate solution), and, after allowing to stand for 15 min, was made up to 50 ml with deionized water.

The emission at 430 nm with excitation at 350 nm was measured with a Perkin-Elmer Model LS3 fluorimeter, set to zero with the corresponding sample solution blank. A standard calibration curve was used for calculations.

Preparation of enzyme extract

A crude enzyme extract was prepared by homogenizing 10 g of raw banana sample in an Omnimixer at 16 000*g* with 50 ml of phosphate buffer (pH 7·0) containing 10 g litre^{-1} insoluble polyvinylpyrrolidone. Homogenization was carried out, with external cooling, for 2 min in 30 s intervals. The homogenate was centrifuged at 16 000*g* at 4°C for 15 min. The supernatant was filtered through a nylon cloth and the volume obtained was carefully measured.

Polyphenol oxidase assay The enzyme activity was determined by measuring the rate of increase in absorbance at 420 nm and 25°C in a Lambda 15 double-beam spectrophotometer (Perkin–Elmer). The reaction mixture contained 2·9 ml of 0·07 M catechol solution in 0·05 M phosphate buffer (pH 7·0) and 100 µl of diluted (1:1, v/v, 0·2 M phosphate buffer, pH 7·0) or undiluted enzyme extract. The activity was calculated on the basis of the slope of the linear portion of the curve of ΔA_{420} plotted against time (up to 3 min). Enzyme activity was expressed as ΔA_{420} min^{-1} g^{-1} FW.

Peroxidase assay The enzyme activity was determined by measuring the rate of increase in absorbance at 485 nm and 25°C of a mixture containing 2·7 ml of 0·05 M phosphate buffer (pH 7·0), 200 µl of *p*-phenylenediamine solution (10 g litre^{-1} in distilled water; hydrogen donor), 100 µl of hydrogen peroxide solution (15 ml litre^{-1}; oxidant) and 25 µl of diluted or undiluted enzyme extract (total reaction volume 3·25 ml). The enzyme activity was calculated on the basis of the slope of the linear portion of a plot of ΔA_{485} against time (up to 3 min). Enzyme activity was expressed as A_{485} min^{-1} g^{-1} FW.

Soluble proteins

Soluble protein concentration in all extracts was determined employing a Bio-Rad kit for the Bradford reaction (Bradford, 1976), with bovine serum albumin as standard.

Aroma analysis

Sample preconcentration

Banana slices (100 g) were placed in a 250 ml round-bottomed flask connected to a pure N_2 source. After 30 min of equilibration, banana flavour vapours were purged during 1 min with a N_2 stream (100 ml min^{-1}) that passed through the silylated quartz insert (90 mm×1 mm i.d.×2 mm o.d.) of the programmed temperature vaporizer (PTV), packed with GasChrom 220, 80–100 mesh, and maintained at 0°C. In this trap, the volatile components, stripped from the sample, were collected. The quartz liner was then inserted into the injector body of the gas chromatograph. Subsequently, the volatile compounds were transferred to the column by the carrier gas once the PTV was ballistically heated.

Gas chromatographic–mass spectrometric analysis

A gas chromatograph (Perkin–Elmer 8500) equipped with a PTV injector was used in this work. Thermal desorption was carried out by increasing the temperature at 14°C s^{-1} from 30°C to 275°C and holding at 275°C for 10 min. Desorption was carried out in the splitless mode. The chromatographic analysis was performed on a Chrompack 50 m×0·25 mm fused silica capillary column, coated with a 0·25 µm immobilized film of CP-Sil-5-CB. Helium at 25 p.s.i. was used as carrier gas; the column temperature was 40°C for 5 min and then programmed at 5°C min^{-1} to 250°C.

Volatile compounds were identified by comparison of the spectra with those in a general purpose library, using an ion trap detector (Perkin–Elmer ITD-50) linked to the chromatographic column. In addition, their identity was confirmed by matching their mass spectrometric spectra with those obtained from authentic reference compounds in the same conditions and equipment. Quantitative analysis was based on the ratios between the areas of the identified peaks and the area corresponding to the internal standard (1 µl of methyl octanoate added to the sample).

Sensory analysis

A trained ten-member panel was selected to evaluate the banana cultivar quality. The sensory laboratory complied with the UNE norms (UNE, 1976). At each session, random duplicate samples of each variety were assessed for appearance/colour, flavour/taste and firmness, each on a structured scale of 1–5. For overall aceptability, the scale range was 1–10 (Dethmers, 1981).

Appearance/colour	Score	Taste/flavour	Score
White yellow	5	Very sweet	5
Pale yellow	4	Less sweet	4
Yellow	3	Sweet	3
Brownish yellow	2	Fairly sweet	2
Brown	1	Dull	1
Firmness	**Score**	**Overall acceptability**	**Score**
Extremely firm	5	Like very much	9–10
Very firm	4	Like	7–8
Firm	3	Acceptable	5–6
Slightly firm	2	Slightly dislike	3–4
Soft	1	Dislike	1–2

Statistical analysis

Data were statistically analysed by an analysis of variance (ANOVA) and mean separation was by Duncan's multiple range test at $P \leq 0.05$, using the INSTAT program. Significant differences were indicated by different letters in the same row.

RESULTS AND DISCUSSION

The main morphological characteristics of the three banana fruit cultivars are summarized in Table 1. The Spanish Gran Enana banana fruit was smaller in size and its length:diameter ratio lower compared with the Spanish Enana and Latin-American Enana fruits. At the proper stage of maturity of bananas from the Cavendish group, the fruit weight (W) is 133–140 g and the length (L) is 16·3–17·7 cm; the quotient (W/L) varies from 7·9 to 8·3 (Salunke, 1984). Such values are determined for each cultivar separately. The diameter of the outer central finger of the second hand (which is about 3·37 cm) is used as a maturity index for bananas in Central America (Purseglove, 1972). In the present work, a maturity index was pre-established (yellow–green peel colour, 70:30) in order to evaluate all cultivar characteristics. In addition, this maturity index was at the right ripening stage to obtain the best processing conditions for banana products (Cano *et al.*, 1990*a*,*b*). The quotient W/L in the Spanish banana cultivars varied between 9·37 for Enana and 7·96 for Gran Enana, while Latin-American Enana had a value of 11·51. The W/L quotient for Spanish cultivars agreed with the quotient for Dwarf Cavendish bananas at the proper stage of maturity reported by Salunke (1984). However, the Latin-American Enana cultivar exhibited the greater fruit weight and length, which produced the higher W/L quotient of this cultivar.

Spanish cultivars were sweeter than the Latin-American cultivar. Skin colour is another important parameter which may distinguish between cultivars. Spanish banana fruits, Enana and Gran Enana cultivars, seemed to be more susceptible to the development of brown spots in the skin, but this was not indicative of any quality problem in banana flesh. Among the parameters more suitable for grading bananas into classes of physiological maturity were (in the case of intact fruit) the skin colour and the ratio pulp:peel weight (Salunke, 1984). Significant differences ($P \leq 0.05$) were found in fruit weight and fruit length for the banana varieties studied in this work.

Results of the physical and physicochemical determinations of banana fruit flesh are shown in Table 2. All determinations were carried out in banana fruits at the same stage of ripeness characterized by peel colour (yellow–green, 70:30). Firmness values were higher in the Spanish Enana cultivar, but there were no significant differences between the fruits of the Spanish Enana and Gran Enana cultivars. However, there was a significant difference ($P \leq 0.05$) between the Enana cultivars regarding their origin. The Latin-American banana, cultivar Enana, had a low firmness value, 5·53 N g^{-1} FW, at the yellow–green peel colour 70:30 ripeness stage. Usually, firmness differences could be correlated to the different amounts of structural polysaccharides, starch and pectic substances found in the

Table 1. Morphological characteristics of banana fruits (yellow–green peel colour, 70:30)

Characteristic	Cultivar		
	Spanish Enana	Spanish Gran Enana	Latin-American Enana
Fruit weight (g)	157·13 ± 14·16a	113·79 ± 14·29b	236·75 ± 22·32
Fruit length (cm)	16·77 ± 0·62a	14·47 ± 0·86b	20·57 ± 1·07c
Weight/length ratio	9·37 ± 0·34a	7·86 ± 0·78b	11·51 ± 0·96c
Maximum fruit diameter (cm)	3·9 ± 0·15a	3·6 ± 0·21b	4·1 ± 0·3c
Shape	Curved	Curved	Straight
Flesh colour	Pale yellow	Pale yellow	White yellow
Taste	Fairly sweet/aromatic	Fairly sweet/aromatic	Dull/fairly aromatic

Values are the mean (± SD) of at least 15 determinations. Different letters in the same row indicate significant differences ($P \leq 0.05$).

Table 2. Physical and physicochemical characteristics of banana fruit pulp

Characteristic	Cultivar		
	Spanish Enana	Spanish Gran Enana	Latin-American Enana
Firmness (N g^{-1} FW)	6·68 ± 0·50a	6·13 ± 0·17ab	5·53 ± 0·41b
Colour			
L	60·11 ± 1·18a	67·12 ± 0·49b	59·25 ± 0·72a
aL	1·16 ± 0·09a	2·94 ± 0·24b	−3·09 ± 0·61c
bL	26·10 ± 0·25a	24·03 ± 0·54b	20·64 ± 0·45c
Hue (h = arctan[bL/aL])	87·45 ± 0·15a	83·02 ± 0·34b	81·49 ± 0·56c
pH	4·74 ± 0·03a	4·91 ± 0·05b	4·83 ± 0·01ab
Titratable acidity (g citric acid per 100 g FW)	0·50 ± 0·03a	0·35 ± 0·01b	0·35 ± 0·04b
Soluble solids (Brix degrees)	24·56 ± 0·33a	21·36 ± 0·14b	16·30 ± 0·03c
Total solids (g per 100 g FW)	26·76 ± 0·13a	25·96 ± 0·17b	23·95 ± 0·17c
Moisture content (g per 100 g FW)	73·24 ± 0·11a	74·04 ± 0·15b	76·05 ± 0·19c

Different letters in the same row indicate significant differences ($P \leq 0.05$).
FW, fresh weight.
Values are the mean (± SD) of at least 15 determinations.

banana flesh. These possible correlations will be described below, with the chemical characteristics of banana fruits.

Objective colour parameters (Table 2) showed significant differences between cultivars Enana and Gran Enana, but not in terms of cultivar origin. Thus, Latin-American banana fruits, cultivar Enana, exhibited a lower luminosity ($L = 59 \cdot 25$), but this value was not significantly different from that of the Enana banana fruit harvested in the Canary Islands ($L = 60 \cdot 11$). However, the Gran Enana cultivar showed the higher luminosity ($L = 67 \cdot 12$). For the other Hunter Lab parameters, *aL* and *bL*, the three banana cultivars were significanly different. The most yellowish flesh was found in Spanish Enana fruits ($bL = 26 \cdot 10$), followed by Spanish Gran Enana ($bL = 24 \cdot 03$); the least yellow was the Latin-American banana flesh ($bL = 20 \cdot 64$). Similar results were obtained for the *aL* parameter (red–green colour) (Table 2). A negative aL value was obtained only for the Latin-American banana cultivar ($aL = -3 \cdot 09$), indicating a green flesh. The hue parameter, $h = \arctan(bL/aL)$, for each banana cultivar gave useful information. The Spanish banana cultivar Enana had the highest value ($h = 87 \cdot 45$), indicating that these fruits were more yellow than the other two varieties (Spanish Gran Enana, $h = 83 \cdot 02$; Latin-American Enana, $h = 81 \cdot 48$).

pH values ranged between 4·7 and 4·9 in banana fruits (Table 2). There was a significant difference between Spanish cultivars, with Spanish Gran Enana having the lower pH value for the fruit stage of ripening characterized by a yellow–green peel colour of 70:30. However, there were no significant differences in this parameter between Enana fruits harvested in different areas. Similar results were obtained for titratable acidity (Table 2) where the Spanish banana fruits had the highest titratable acidity (0·5 g citric acid per 100 g FW).

Banana cultivars also exhibited differences ($P \leq 0.05$) in terms of soluble and total solids (Table 2). The banana cultivar showing the highest level of soluble solids was again the Spanish Enana, 24·56, followed by the Spanish Gran Enana (21·36) and the Latin-American Enana (16·30). This last cultivar had a 35% lower content of soluble solids compared with the same variety harvested in the Canary Islands. The Latin-American banana cultivar had the lowest amount of total solids; this related to the lower firmness values at the same ripening stage. In addition, all varieties of banana showed significant differences in total solids and moisture content (Table 2). In general, the moisture content of banana fruits increased when the fruit became ripe. This could be the result of breakdown of carbohydrates during respiration, the hydrolysis of starch, and moisture transfer from the peel to the pulp by osmosis (Barnel, 1940; Palmer, 1971). However, there are cultivar differences in terms of these biochemical processes, which could result in significant differences in banana moisture content. Latin-American cultivar Enana showed the higher moisture content (76·05 g per 100 g FW), followed by the Spanish cultivar Gran Enana (74·04 g per 100 g FW) and then the Spanish cultivar Enana (73·24 g per 100 g FW), all these values being significantly different ($P \leq 0.05$).

The chemical and biochemical characteristics of banana fruits are shown in Table 3. The total soluble sugars were significantly different in the three banana cultivars. The highest amount of total sugars was found in the Spanish Gran Enana fruits (11·07 g per 100 g FW), but this cultivar also had the lowest amount of sucrose (5·53 g per 100 g FW). This shows that the contribution of soluble monosaccharides (fructose and glucose) to the total sugars was greater than in the other two banana cultivars. Similarly, Spanish Gran Enana bananas had the highest fructose and glucose contents (2·28 and 3·55 g per 100 g FW, respectively). These results agree with the sensorial perception of sweetness reported in Table 4. One of the most remarkable changes that occurs during ripening of banana pulp is the hydrolysis of starch and subsequent sugar accumulation (Lal *et al.*, 1974). In the banana cultivars studied

Table 3. Chemical and biochemical characteristics of banana fruit pulp

Characteristic	Cultivar		
	Spanish Enana	Spanish Gran Enana	Latin-American Enana
Soluble sugars (% FW)			
Total	10·2 ± 0·15a	11·1 ± 0·32b	8·23 ± 0·20c
Sucrose	6·93 ± 0·35a	5·53 ± 0·05b	5·91 ± 0·15c
Fructose	1·32 ± 0·05a	2·28 ± 0·09b	0·97 ± 0·02c
Glucose	1·95 ± 0·09a	3·55 ± 0·01b	1·34 ± 0·01c
Starch (% FW)	6·86 ± 0·41a	10·02 ± 0·14b	18·03 ± 0·30c
Pectic substances (mg galacturonic acid per 100 g FW)	40·1 ± 5·8a	57·7 ± 5·7b	23·2 ± 6·1c
Vitamin C (mg ascorbic acid per 100 g FW)	33·5 ± 0·23a	33·2 ± 0·60a	29·3 ± 0·31b
Soluble proteins (mg per 100 g FW)	2·87 ± 0·02a	2·66 ± 0·10b	0·46 ± 0·12c
Peroxidase activity (ΔA min^{-1} g^{-1} FW)	9·61 ± 2·6a	2·28 ± 0·12b	1·41 ± 0·45c
Polyphenol oxidase activity (ΔA $min^{-1}g^{-1}$ FW)	13·8 ± 0·61a	13·7 ± 0·02a	6·92 ± 0·2b

Different letters in the same row indicate significant differences ($P \leq 0.05$).
FW, fresh weight.

Table 4. Identified compounds and peak area/internal standard area ratios corresponding to the head space of the three banana cultivars

Volatile compound	Cultivar		
	Spanish Enana	Spanish Gran Enana	Latin-American Enana
Butane-2,3-dione	0·59	0·16	0·01
Ethyl acetate	1·13	0·16	0·45
Pentane-2-one	1·18	0·07	0·46
Ethanol	0·00	0·00	0·16
1-Butanol	0·00	0·00	0·56
Hexanal	0·00	0·00	0·26
Isoamyl acetate	0·31	0·16	0·08
1-Pentanol	0·51	0·10	0·02
Hexyl acetate	0·47	0·38	0·00
Heptanal	0·77	0·57	0·07
1-Hexanol	0·10	0·07	0·03
Hexyl butanoate	0·08	0·02	0·00
Octanal	0·08	0·01	0·00
Acetic acid	0·06	0·04	0·02
Decanal	0·14	0·01	0·00
Benzaldehyde	0·03	0·01	0·01

in this work, considerable hydrolysis of starch had taken place at the yellow–green (70:30) stage of maturity. The Latin-American Enana fruits had the largest amount of starch (18·03% FW), followed by the Spanish Gran Enana (10·02% FW) and Enana (6·86% FW) cultivars. However, Latin-American bananas had the lowest content of total pectic substances (23·2 mg galacturonic acid per 100 g FW), with the Spanish Gran Enana cultivar having the highest amount (57·7 mg galacturonic acid per 100 g FW) (Table 3).

Table 3 shows the vitamin C content of the three banana varieties. Spanish varieties of banana exhibited the highest vitamin C values (33·52 and 33·21 mg ascorbic acid per 100 g FW, for Enana and Gran Enana, respectively). The Latin-American variety was the only one significantly lower in terms of vitamin C content (29·32 mg ascorbic acid per 100 g FW).

The soluble protein contents of the banana cultivars also showed significant differences. The Spanish Enana cultivar had the highest amount of protein, followed by the Gran Enana cultivar (2·87 mg per 100 g FW and 2·66 mg per 100 g FW, respectively). The Latin-American bananas had the lowest amount of protein (0·46 mg per 100 g FW, which is 80–85% less than the Spanish varieties).

An evaluation of two oxidoreductases, polyphenol oxidase (PPO, EC 1.14.18.1) and peroxidase (POD, EC 1.11.1.7) was made in order to establish possible differences between banana cultivars. These enzymes are closely related to the development of browning in fruit tissue, and for this reason their characterization is relevant to the suitability of banana cultivars for certains types of processing. Table 3 shows the values obtained for soluble polyphenol oxidase and soluble peroxidase in flesh of the three banana cultivars studied. Polyphenol oxidase activity was significantly lower in the Latin-American cultivar Enana. These banana fruits also had the lowest peroxidase activity. These results correlated with the value obtained for total soluble proteins in this variety, which was lower than for the two Spanish banana varieties. Both enzymic activities in Latin-American fruits were almost one-half the

activities of Spanish varieties. Fruits containing higher levels of enzymic activity may exhibit a faster browning rate when the fruit flesh is exposed to the air during preparative operations on processing lines (peeling, cutting, slicing, etc.). The Spanish cultivars showed significant differences in peroxidase activity, but no significant differences were found in polyphenol oxidase activity. Browning seems more likely to take place in Spanish Enana banana fruits undergoing preparative operations. Some authors (Toraskar & Modi, 1984) have established the importance of peroxidase activity in the development of chilling injury in banana fruits exposed to temperatures below 10°C. Chill-injured bananas showed low peroxidase activity compared to fruit stored at normal ripening temperature, and the study suggested that peroxidase may be one of the enzymes affected during low-temperature storage. Banana cultivars that exhibit a higher peroxidase activity could therefore be more susceptible to chilling injury problems during handling and transport. Spanish banana cultivars showed a seven-fold (Enana) and two-fold (Gran Enana) higher peroxidase activity compared to the Latin-American cultivar Enana at the same maturity stage (Table 3). From these results, this latter banana variety would be likely to be more resistant to handling and transport, making export easier. However, sensory analysis of Spanish bananas showed that these fruits have more flavour and sweetness.

Banana flavour is mainly caused by esters, although appreciable quantities of free alcohols have also been reported (Blanch *et al.*, 1993; Perez *et al.*, 1993; Shiota, 1993). The analysis of fruit flavour requires the isolation of the volatile compounds from the matrix prior to separation by gas chromatography. Dynamic headspace analysis is more efficient than the static technique for the enrichment of trace compounds (Benelmans, 1985). In recent years, the programmed temperature vaporizer (PTV) has been used as a precolumn enrichment device, its liner packed with an adsorbent (Tabera *et al.*, 1991). Table 4 shows the compounds identified and the ratios of peak area/internal standard area corresponding to the GC-MS of the purge and trap analysis of the three banana cultivars studied. The sample isolation procedure used allowed the extraction of the volatile components contributing most to the banana aroma as perceived by consumers. Quantifiable differences among the flavours of the banana cultivars were found. Spanish Enana fruit was found to be the richest in flavour compounds.

McCarthy *et al.* (1963) classified the various components of banana aroma. A banana-like flavour was assigned to the amyl and isoamyl esters of acetic, propionic and butyric acid, whereas the alcohols and carbonyls gave odours described as green, woody, or musty. In the present study, the Latin-American banana flavour showed the presence of ethanol, 1-butanol and hexanal, but these compounds were not found in either of the Spanish banana varieties. This finding could be related to the observed differences in sensory aroma perception by panellists. Also, only Spanish bananas showed the presence of hexyl butanoate, which is related to a banana-like flavour.

The results of the test panel are reported in Table 5. In the acceptance tests, panellists preferred the colour and taste/flavour of the Spanish banana cultivars; of the two Spanish varieties, cultivar Enana was rated higher in colour (8·15) and taste/flavour (8·25), while cultivar Gran Enana scored 7·14 for taste/flavour and 7·86 for colour. However, statistical analysis of these sensory data did not show any significant difference between the samples. The same conclusion could be obtained from the sensory data of the Latin-American fruit. The panellists rated them 6·50 for taste/flavour and 5·75 for colour; they were also able to discern the origin of the samples (Spanish or Latin-American). Again, however, statistical evaluation showed no significant differences between cultivars. Results from overall aceptability tests yielded the same conclusion. There were no significant differences between banana cultivars or origin of the fruit.

However, different conclusions were obtained from studying the results from sensory descriptive tests for each quality parameter in Table 4. Panellists were able

Table 5. Sensory analysis of banana fruits (pulp)

Characteristic	Cultivar		
	Spanish Enana	Spanish Gran Enana	Latin-American Enana
Descriptive test			
Colour	3·62 ± 0·51a	4·28 ± 0·48a	5·00 ± 0·01b
Taste/flavour	3·50 ± 0·51a	3·14 ± 0·69a	2·25 ± 0·36b
Firmness	2·87 ± 0·83a	3·57 ± 0·53a	3·00 ± 0·75a
Acceptance test			
Colour	8·15 ± 1·35a	7·86 ± 1·46a	6·50 ± 1·51a
Taste/flavour	8·25 ± 1·83a	7·14 ± 1·77a	5·75 ± 1·16a
Firmness	8·00 ± 1·69a	7·86 ± 1·86a	7·00 ± 2·20a
Overall acceptability	8·13 ± 1·07a	7·62 ± 1·32a	6·41 ± 1·37a

Different letters in the same row indicate significant differences ($P \leq 0{\cdot}05$).

to differentiate banana flesh colours and categorized them as yellow for Spanish Enana, pale yellow for Spanish Gran Enana and white-yellow for the Latin-American Enana cultivar. Similar conclusions were obtained from the taste/flavour evaluation. The Spanish Enana taste was categorized as sweet (3·5) as also was the Spanish Gran Enana (sweet, 3·14). However, the Latin-American Enana was rated as fairly sweet (2·25). Statistical analyses of the data from these descriptive tests showed significant differences ($P \leq 0{\cdot}05$) between Spanish banana cultivars and the Latin-American cultivar. However, between Spanish banana fruits there were no significant differences. The other quality parameter, firmness, was not useful in differentiating cultivars. Panellists rated all samples as firm, but Spanish Enana was the lowest.

Some correlation could be obtained between the physicochemical and chemical characteristics of banana fruits and their corresponding sensory appreciation. Objective colour measurements showed that Spanish Enana flesh was more yellow (higher *bL* value) than the other two cultivars. This conclusion agreed with the sensory description of the flesh colour. Similar results were obtained for the less yellow banana flesh, which corresponded to the Latin-American cultivar from both sensory and objective colour evaluations. A significant correlation was obtained between sucrose + fructose and the sensory perception of sample sweetness. In this respect, Spanish Enana was the cultivar ranked as more sweet (3·5), having a sucrose + fructose content of 8·25 g per 100 g FW, while Spanish Gran Enana was ranked as 3·14 (also sweet, but less than Spanish Enana) with a sucrose + fructose content of 7·81 g per 100 g FW. However, total sugars showed no correlation with the sensory tests, probably because of the levels of glucose, a less sweet monosaccharide. Thus the Latin-American banana cultivar was the least sweet, because of the lower sucrose + fructose content and lower total sugars concentration. Analytical evaluation of aroma compounds also confirmed the results of the sensory flavour acceptance test. Spanish Enana fruits scored highest in flavour intensity, and this cultivar was also the most flavoured banana in terms of levels of volatile compounds.

Sensory assessment of firmness did not show any significant difference between banana cultivars, either by descriptive or by acceptance tests (Table 5). Objective determination of banana slice firmness by Kramer shear press was able to differentiate between the Spanish and Latin-American Enana cultivars, but not between the two Spanish banana cultivars (Table 2). Also, chemical determination of starch and pectic subtances did not allow differentiation of banana varieties, because at the same pre-established maturity index (yellow–green peel colour, 70:30) the values obtained for the contents of starch and pectic substances did not correlate significantly with the firmness values, or with the sensory evaluation.

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