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Distribution of Nutrients in Edible Banana Pulp

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Summary

Chemical composition in different parts of banana pulp was determined. Ash and protein mean concentrations in the central part of the pulp were higher than in the medium part, and these were higher than those in the external part. The mean concentrations of the fiber (total and non-soluble) in the central part were higher than those found in the other parts. Ascorbic acid behaved inversely; the mean concentration significantly decreased from the external part to the central part. The central part contained the highest mean concentrations of the analysed minerals (Na, K, Ca, Mg, Fe, Cu, Zn and Mn), with statistically significant differences for Cu, Zn and Ca. A tendency to differentiate the pulp samples of banana as a function of the part considered was observed after using factor analysis. The samples from the central part were different from those from the external part. The samples of the medium part overlapped with those of the other two parts.

Key words: bananas, chemical composition, parts of banana pulp

Introduction

Banana is a climacteric fruit made up of peel and edible pulp that has a high nutritional value. Edible bananas are vegetatively parthenocarpic berries; *i.e.*, they develop a mass of edible pulp without pollination. The fruit develops from the inferior ovary of the female flower. The ovules shrivel early but may be recognised in the mature fruit as minute brown flecks in the central part of the edible pulp. The pulp:peel ratio increases during the development of the fruit, from 1:1 to 4:1, depending on the variety and maturity at harvest. During the storage ripening the starch declines from 20–23 to 1 % and at the same time the soluble sugar increases from less than 1 to 20 %. When the mature fruit ripens, the pulp:peel ratio increases, partly as a result of water movement from the peel to the pulp associated with an increase of osmotic pressure in the pulp caused by the hydrolysis of starch (*1–3*).

There are two cultivars produced in the Canary Islands: »Gran Enana« and »Pequeña Enana«, belonging to the »*Musa acuminata AAA*« (species Cavendish). The production of bananas in Canary Islands accounts for 3.4 % of the world market share. A 9300 h, approximately 20 % of agricultural land in the Canary Islands, are used for farming bananas, and 35 000 people are, directly or indirectly, employed in this farming (*4*).

Almost half of the bananas produced in the world are eaten raw as a dessert fruit; the other half is cooked, usually by frying, boiling, roasting or baking. Virtually all varieties may be either eaten raw when ripe, or cooked

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when either ripe or green. Cultural preferences govern the choices made. Bananas can also be processed in various ways so that they may be stored for longer periods and utilised for other purposes. Banana purée is the most important processed product made from ripe fruit. The purée can be used as ingredient in dairy desserts, bakery items, drinks, processed foods and sausages. Ripe bananas are also sliced and canned in an acidified syrup and are used in desserts, fruit salads, cocktail drinks and bakery items. Chips are made by deep-frying thin slices of unripe fruits. Ripe bananas can be dried and stored satisfactorily for years without addition of preservatives (*1–3*).

The chemical distribution of nutrients in fruits varied according to the anatomic part. The seeds or zones next to them present higher concentrations of protein, ash and fiber. Spanish paediatricians usually recommend to eliminate the central part of the bananas when the bananas are introduced in the feeding of children. This is due to difficult digestion of this central part and, besides, this central part is often rejected by children. Thus, it is interesting to know the distribution of nutrients in different parts of the bananas. It would also be interesting to estimate the losses of vitamin C and other nutrients during frying. There are no reports on the distribution of chemical compounds in edible banana pulp. In this paper we have established the distribution of chemical compounds in several parts of edible banana pulp.

Materials and Methods

Samples

The three parts of edible banana pulp have been analysed: (*i*) external part, approximately 1 mm from the superficial part is considered; (*ii*) medium part containing the pulp of the fruit; (*iii*) central part including the seeds (0.5 cm in diameter).

Eight bananas from two clusters from the North of the Island of Tenerife were sampled. Each banana was separated in the three parts described. Twenty four samples of these parts of banana pulp were analysed. Bananas for the preparation of samples were taken from the second »hand« of the upper part of the banana cluster. The »hands« were cut when green colour (maturation colour: point No. 1) and were ripened in the laboratory using »Ketefon« and stored at room temperature. When the colour of the banana samples was »yellow« (maturation colour: point No. 6), four bananas from two »hands« were collected, and a »pool« was obtained by mixing different parts of banana pulp.

Analytical methods

Each pulp sample of banana parts was perfectly homogenised using a Turmix (T-25 Basic, Ika). The homogenised sample was divided into four fractions: (*i*) the mass of 3 g was used for determining moisture and ash; (*ii*) the mass of 25 g was desiccated at 55 °C (5 days) for determining fiber and metals; (*iii*) the mass of 10 g was desiccated at 105 °C for determining protein; and (*iv*) the rest was used for determining sugars. The analysis of ascorbic acid was carried out independently on the above mentioned parts of three bananas in duplicate.

Moisture was determined on three replicates by desiccation at 105 °C for 24 h, according to the method described in AOAC (*5*). Ash was determined in triplicate by heating the residue of moisture determination at 550 °C for 24 h. Other analyses were performed in duplicate. Nitrogen content was obtained by applying the Kjeldahl method (*5*), and the protein content was calculated using a nitrogen factor of 6.25. Total and nonsoluble fiber were determined according to the methods proposed by Prosky (*6–7*). Ascorbic acid was determined by the dichlorophenol indophenol titration procedure (*5*). Ascorbic acid was extracted using a solution of acetic and metaphosphoric acid.

Sugar analyses were performed by HPLC (Waters chromatograph) using a Refractive Index Detector (Model 2410) and a Sugar Pak™ column (Waters, 6.5·300 mm). All the sugars were extracted from 3 g of homogenised banana in 20 mL of ethanol solution (80 %). The solution then passed through a 0.45 µL filter (Millipore, HATF01300) and then through the Sep-Pak^R Cartridge (WAT020515), which was activated with 5 mL of methanol and 5 mL of ultra pure water. One millilitre of the filtration solution of each sample passed through the Sep-Pak^R Cartridge. The Cartridge was then washed with 5 mL of water (Mill-Q). Glucose, fructose and sucrose concentrations were determined by injecting 20 µL of standard solutions or sample extracts and eluting by mobile phase (the mass of 50 mg of Calcium-Titriplex dihydrate (Merck) in one litre of ultrapure water) at a flow rate of 0.5 mL/min. The temperature of the column was maintained at 90 °C. The HPLC peaks were identified by comparing the retention times with those of commercial standards of sucrose, glucose and fructose by Sigma (Madrid, Spain).

Metal fraction was determined using a Varian Spectra AA (10 Plus) atomic absorption spectrometry equipped with a D_2 lamp background correction system using flame air-acetylene. Determinations were carried out in triplicate. Between 1 and 1.2 g of dried banana samples were weighed into digestion tubes and 8 mL of HNO_3 Suprapure (Merck) was added. The mixture was heated into a digestion block in the following sequence: 100 °C/15 min, 125 °C/15 min, 150 °C/60 min, 160 °C/60 min and 170 °C/15 min. After cooling at room temperature, 0.5 mL of HCl Suprapure (Merck) was added and heated to 170 °C/5 min. Then, this solution was quantitatively transferred and adjusted to 10 mL with ultra pure water. For the determination of K, Ca and Mg, it was necessary to make a further dilution, taking 1 mL of the concentrated solution and adjusting it to 10 mL with ultra pure water. Ca, Mg, Fe, Cu, Zn and Mn were determined by atomic absorption spectrometry, and Na and K were determined by atomic emission spectrometry using the instrumental conditions recommended.

Quality control

Methods were validated with certified reference material. The Rye CRM-381 was used for protein, ash, soluble and total fiber determinations. Moisture was not certified. Wheat Flour Reference Material (ARC/CL3, LGC

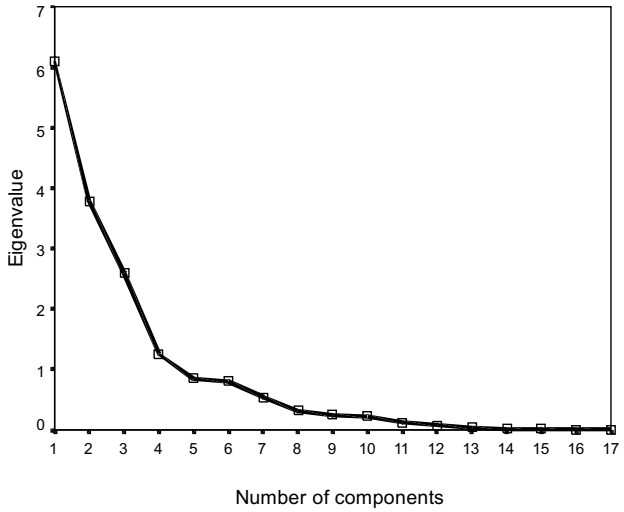

Fig. 1. Representation of the eigenvalues for all the principal components extracted

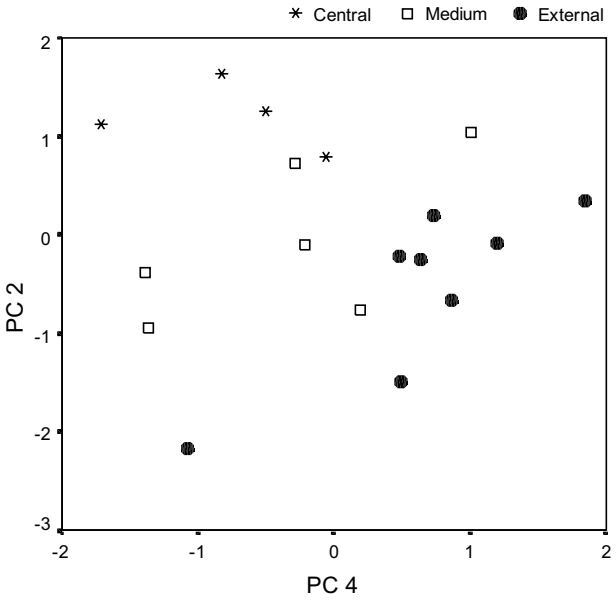

Fig. 2. Extracted principal components for all the banana samples differentiated according to the part of banana analysed, represented in the plane defined by the PC 2 and PC 4

Deselaers) was used for metals, except for Mn. Quality control for sugars, ascorbic acid and Mn were checked using banana samples spiked and not spiked with standards. The recovery percentage ranged from 97.5 to 101.5 %. The coefficient of variations ranged between 0.68 and 5.62 %.

Statistics

All statistical analyses were performed by means of the SPSS version 10.0 software for Windows. The Kolmogorow-Smirnov's test was applied to verify that the distribution of the variable was normal, $p<0.05$. Mean values obtained in different groups were compared by One-Way ANOVA and *t*-test, assuming that there were significant differences between mean values when statistical comparison was $p<0.05$. Factor analysis, using principal components as the method for extraction of factors, was used to summarise the information in a reduced number of factors and to differentiate the samples of banana pulp as a function of the part considered.

Results and Discussion

Table 1 shows mean concentrations and standard deviation, maximum and minimum concentrations of moisture, ash, protein, total and non-soluble fiber, sugars (sucrose, fructose and glucose) and ascorbic acid in the three parts (external, medium and central) considered. The mass fraction of these nutrients obtained in this work was within the same range of data reported in Food Composition Charts (*8*,*9*). It can be emphasised that in the samples of bananas analysed monosaccharides (glucose and fructose) were lower and sucrose was higher than the values indicated in the Food Composition Chart (*9*). The moisture concentration did not change significantly according to the pulp part analysed, although the external part presented the highest mean concentrations. Ash and proteins behaved in a similar manner. Mean concentrations in the central part were higher ($p<0.05$) than those in the medium part, and these were higher ($p<0.05$) than the concentrations found in the external pulp. Higher contents of ash and proteins in the central part could be due to the presence of ovules. It is well known that, in general, the seeds and ovules of fruits and vegetables have high contents of both nutrients. Total and non-soluble fiber and sugars (glucose, fructose, and sucrose) also had the highest mean concentrations in the central part of the edible banana pulp. Mean concentrations of total and non-soluble fiber, glucose and fructose in the central part, were higher ($p<0.05$) than those in the external part. Sucrose did not show any statistically significant differences between the mean concentrations obtained in the three analysed parts of edible bananas. However, the concentration of ascorbic acid decreased from the external to the central part. Thus, the mean concentration in the external part was significantly ($p<0.05$) higher than the mean concentration in the medium part, and this was higher ($p<0.05$) than the mean concentration in the central part.

Na, K, Ca, Mg, Fe, Cu, Zn and Mn contents were also determined in the three parts of banana pulp (Table 2). Comparing the data observed here with others found in Food Composition Charts in the literature (*8*,*9*), one can observe that our data were higher for K, similar for Mg and lower for Na and Ca, as well as for the trace elements analysed. The highest concentrations were found for K, followed by Mg, Ca and Na. Fe and Zn showed lower concentrations, and the lowest were trace elements Cu and Mn. The central part showed higher mean content of the studied metals than the other two parts, similar to the before mentioned nutrients. The central part of the bananas had higher mean concentration of Cu ($p=0.014$) and Zn ($p=0.054$) than the medium part, which had higher mean contents than the external part. Ca, Mn and Na mean content in the central part were also

Table 1. Chemical composition in mass fraction (%) in the banana pulp according to the part of banana[1]

Parts	*w*(moisture)	*w*(ash)	*w*(protein)	*w*(total fiber)	*w* (non-soluble fiber)	*w*(sucrose)	*w*(glucose)	*w*(fructose)	*w*(ascorbic acid)
External	73.45±2.18^{a} (69.53–75.37)	0.97±0.09^{a} (0.86–1.10)	0.95±0.06^{a} (0.89–1.06)	2.39±0.27^{a} (2.00–2.78)	1.93 ± 0.19^{a} (1.67–2.22)	12.27± 2.35^{a} (8.41–14.81)	1.63 ± 0.45^{a} (1.03–2.09)	1.54 ± 0.43^{a} (0.92–2.04)	14.82 ± 4.29^{b} (6.96–19.97)
Medium	71.94 ± 2.05^{a} (69.15–74.79)	1.10 ± 0.12^{b} (0.90–1.23)	1.17 ± 0.03^{b} (1.12–1.20)	2.54 ± 0.32^{ab} (2.15–3.12)	1.94 ± 0.26^{a} (1.51–2.28)	12.65 ± 1.43^{a} (11.02–14.71)	1.82 ± 0.50^{ab} (1.18–2.64)	1.64 ± 0.43^{ab} (1.05–2.41)	11.20 ± 3.15^{a} (5.61–15.76)
Central	72.17 ± 1.05^{a} (70.61–73.67)	1.28 ± 0.13^{c} (1.09–1.50)	1.40 ± 0.07^{c} (1.27–1.46)	2.89 ± 0.62^{b} (2.16–3.65)	2.19 ± 0.15^{b} (1.97–2.41)	14.43 ± 1.16^{a} (13.04–15.60)	2.40 ± 0.47^{b} (1.84–3.00)	2.18 ± 0.50^{b} (1.53–2.75)	8.48 ± 2.39^{a} (5.35–13.06)

[1] Results in the same vertical line with the same superscript were not significant ($p<0.05$)

Table 2. Metal average mass fraction (ppm) in the banana pulp according to the part of banana[1]

Parts	*w* (Fe)	*w* (Cu)	*w* (Zn)	*w* (Mn)	*w* (Na)	*w* (K)	*w* (Ca)	*w* (Mg)
External	2.44±0.32^{a} (1.84–2.82)	0.268±0.119^{a} (0.19–0.55)	0.985±0.209^{a} (0.67–1.39)	0.537±0.162^{a} (0.32–0.75)	3.36±0.76^{a} (2.39–4.74)	4692±296^{a} (4347–5173)	33.6±11.9^{a} (17.4–57.1)	364.6±54.9^{a} (303–479)
Medium	2.45±0.30^{a} (2.04–2.88)	0.353±0.101^{ab} (0.22–0.59)	1.12±0.23^{ab} (0.84–1.40)	0.499±0.184^{a} (0.31–0.74)	2.91±0.62^{a} (2.18–3.84)	4602±126^{a} (4419–4717)	33.1±10.7^{a} (20.8–47.5)	400.1±52.3^{a} (298.3–451)
Central	2.46±0.29^{a} (1.95–2.84)	0.48±0.14^{b} (0.24–0.65)	1.29±0.25^{b} (0.83–1.54)	0.782±0.402^{a} (0.36–1.42)	4.03±1.79^{a} (2.27–7.58)	4797±368^{a} (4336–5475)	51.9±24.3^{a} (21.8–92.5)	406.2±45.2^{a} (322–423)

[1] Results in the same vertical line with the same superscript were not significant ($p<0.05$)

Table 3. Results of the factor analysis of the data matrix

Components	Eigenvalue	Variance %	Cumulative variance %
1	6.096	35.86	35.86
2	3.783	22.25	58.11
3	2.596	15.27	73.38
4	1.255	7.382	80.76
5	0.851	5.005	85.77
6	0.804	4.732	90.50
7	0.541	3.180	93.68
8	0.318	1.873	95.55
9	0.244	1.435	96.99
10	0.231	1.358	98.35
11	0.118	0.694	99.04
12	0.081	0.477	99.52
13	0.042	0.246	99.76
14	0.021	0.125	99.89
15	0.0179	0.105	99.99
16	0.0009	0.005	99.99
17	0.0003	0.002	100.00

Table 4. Factor matrix obtained after a Varimax rotation

	PC 1	PC 2	PC 3	PC 4
Moisture	**–0.947**	0.052	–0.121	0.126
Mn	0.811	–0.449	0.034	0.042
K	0.793	–0.113	0.168	0.268
Total fiber	0.714	–0.085	0.252	–0.148
Na	0.562	–0.145	–0.402	0.150
Glucose	–0.389	**0.819**	–0.303	–0.132
Sucrose	–0.249	0.812	0.052	0.099
Fructose	–0.384	0.794	–0.372	–0.152
Ascorbic acid	–0.086	–0.786	–0.046	0.313
Protein	–0.008	0.714	0.311	–0.603
Non-soluble fiber	0.015	0.694	0.060	0.190
Cu	–0.144	0.072	**0.949**	–0.036
Mg	0.173	–0.076	0.928	–0.047
Zn	0.198	0.054	0.923	0.118
Ca	0.395	–0.357	0.734	0.135
Fe	0.226	0.116	0.475	**0.711**
Ash	0.604	0.244	0.174	–0.651

higher than those observed in the other parts, without any significant differences between them.

Factor analysis using the principal components as the method for factor extraction was applied to all the samples of edible banana pulp to differentiate the samples according to the part considered and to obtain a more simplified view of the relationship between the analysed chemical compounds. Fig. 1 shows the eigenvalues for all the principal components (PCs) extracted. According to the Kaiser criterion, the first four PCs, because of their eigenvalue higher than 1, could explain more variance than the original variables. The amount of 80.8 % of the total variance was explained with these four PCs (Table 3). A Varimax rotation was carried out to minimise the number of variables influencing each factor and then to facilitate the interpretation of the results (Table 4). The first PC, which explains the higher percentage of variance (35.9 %), is negatively associated with the moisture and positively, to lesser extent, with Mn and K. The second PC is related to sugars (glucose, sucrose and fructose) but negatively to ascorbic acid. The third PC is strongly associated with Cu, Mg and Zn, and the fourth PC weakly with Fe. The score plots for all the banana samples defined by the second and fourth PCs are shown in Fig. 2. It can be observed that the cen-

tral parts of the bananas are clearly separated from the samples collected in the external part. However, no separation was observed between the samples of the medium part and the rest of the banana samples.

Conclusion

Chemical composition in edible banana pulp varied according to the part of the pulp considered. The central part of banana pulp is the richest in nutrients, except for ascorbic acid. Applying the factor analysis, the central and external part can be differentiated according to the chemical composition.

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Raspodjela hranjivih tvari u jestivom dijelu pulpe banane

Sažetak

Određen je kemijski sastav u različitim dijelovima pulpe. Srednje koncentracije pepela i proteina bile su veće u centralnom dijelu nego u srednjem, a obje su bile veće nego u vanjskom dijelu pulpe. Koncentracija vlakana (ukupna i netopljiva) u centralnom dijelu bila je veća nego u ostalim dijelovima. Koncentracija se askorbinske kiseline znatno snizivala od vanjskog prema unutrašnjem dijelu. Centralni dio imao je najveću koncentraciju mineralnih tvari (Na, K, Ca, Mg, Fe, Cu, Zn i Mn) uz značajne statističke razlike udjela Cu, Zn i Ca. Koristeći faktorsku analizu autori su nastojali diferencirati uzorke pulpe kao funkciju pojedinih sastojaka. Uzorci iz centralnog dijela razlikovali su se od onih u vanjskom dijelu, a vrijednosti iz srednjeg dijela preklapale su se s vrijednostima iz druga dva dijela.