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Mineral concentrations in cultivars of potatoes

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Abstract

Concentrations of Na, K, Rb, Ca, Mg, Fe, Cu, Zn and Mn were determined in eight cultivars of potatoes harvested in Tenerife. The traditional cultivars presented higher K, Fe, Cu and Zn concentrations and lower ratio Na/K than recently imported cultivars. The cultivar Cara showed the highest and lowest mean concentration for Na and K, respectively. The highest mean concentrations of Fe, Cu and Zn were found in the cultivars Azucena, Palmera and Peluca, and the lowest concentrations in Cara. The trace elements significantly correlated with all the metals. The behaviour of Na was opposite to the rest of the metals, showing negative correlations. Applying factor analysis, the first three factors explaining 70.4% of the total variance were extracted. The first factor is related to Zn, the second factor is associated with Mn and K, and the third factor is negatively related to Na. Factor analysis and cluster analysis tend to separate the potato samples according to location and irrigation procedure. Traditional and recently imported potatoes were well separated when the factor analysis was applied on the samples of *Solanum tuberosum*.

Keywords: Mineral composition; Cultivars of potatoes; Geographical location; Irrigation system; Factor analysis; Dendogram

1. Introduction

Potatoes are a traditional and basic food and they have an important role in the nutrition of the Canary people (Serra-Majem, Armas Navarro, & Ribas Barba, 1999). After Galicia, the Canary Islands is the Spanish region with the highest per capita consumption of potatoes (estimated to be 143.2 g/person/day) (Serra-Majem et al., 1999). From the economical point of view, 20,000 persons are, either directly or indirectly, involved and depend on the farming of potatoes (Rodriguez Brito, 1992).

There are approximately 20–25 cultivars of potatoes produced in the Canary Islands. According to Gil Gonzalez (1997), these cultivars are classified into two groups:

1. Traditional potatoes, which were introduced to the islands several centuries ago. These cultivars can belong to *Solanum tuberosum* ssp. *andigena*, *Solanum*×*chaucha* and *S. tuberosum* ssp. *tuberosum*. It is supposed that ssp *andigena* and *S.*×*chaucha* are closely related to the potatoes from the Andes, because they probably descend from those that arrived in Tenerife from South America in the sixteenth and seventeenth centuries. Traditional potatoes from ssp. *tuberosum* came from Europe between sixteenth and seventeenth centuries.
2. Recently imported potatoes, which have been imported from the British isles during the past century. These cultivars belong to *S. tuberosum* ssp. *tuberosum*.

The first group of potatoes show peculiar and well differentiated sensorial characteristics. The local government, according to European Union legislation, is currently trying to establish the criteria for quality, food labelling and geographic origin that must be complied with in order to obtain the Certified Brand Origin "Denominación de Origen". The chemical composition of potatoes is influenced by many factors, such as: the production area, cultivars, soil and climate, agricultural

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practice, storage and commercialization conditions (Burton, van Es, & Hartmans, 1992; Gravoueille, 1999; Storey & Davies, 1992). It is recognized that the mineral and trace metal compositions of fruits and vegetables are distorted reflections of the trace mineral composition of the soil and environment in which the plants grow. Therefore, they can be used to distinguish the geographic origin of potatoes (Anderson, Magnuson, Tschirgi, & Smith, 1999).

The main objective of this paper was to determine the concentrations of minerals in eight cultivars of potatoes to differentiate them in relation to taxonomic or production area criteria. A statistical study of correlation, factor analysis, and cluster analysis was carried out to find out relations among minerals and classify the potatoes into homogeneous groups.

2. Materials and methods

2.1. Potato samples

Seventy-seven samples of potatoes were provided by Mercatenerife (Central Market of Tenerife) and Cabildo Insular of Tenerife (Tenerife Government) from different farms located in several regions of the island. They were harvested between March and July of 2000 and no more than 2 weeks were spent from harvest to analysis. Samples were authenticated by technicians of the Instituto Canario de Investigaciones Agrarias and of University of La Laguna. Eight cultivars were analyzed, six of traditional potatoes and two of recently imported potatoes. The main characteristics of potato samples are described in Table 1.

Each potato was hand-rinsed under a stream of tap water for 15–20 s and the dirt was removed by gently rubbing by hand under the water stream. After rinsing, the potatoes wee shaken to remove any excess of water, gently blotted with a paper towel and placed in a laboratory dark place to air-dry prior to processing (1–2 h). Afterward, the potato samples were homogenized and, an aliquot was desiccated and acid-digested for the determination of metals.

Table 1
Description of the potato cultivars according to harvest time, production area and irrigation

Cultivar	*n*	Tuber weight (g)	Harvested time	Location of farm		Irrigation	
				North	South	Yes	No
Bonita[a]	16	34±14	March–July	14	2	3	13
Colorada[a]	9	51±19	April–June	9	6	8	7
Azucena[a]	5	30±9	April–June	9	0	1	8
Negra[a]	15	34±9	March–June	5	0	0	5
Palmera[a]	6	59±30	March–June	6	0	0	6
Peluca[a]	6	71±19	March–June	5	1	1	5
Cara[2]	10	94±39	March–June	5	5	8	2
Kerr's Pink[b]	10	97±19	March–July	6	4	7	3

[a] Cultivars from traditional potatoes.
[b] Cultivars from recently imported potatoes.

2.2. Analytical methods

Metal content was determined using a Varian Spectra AA-10 Plus atomic absorption spectrometer equipped with a D_2 lamp background correction system using an air–acetylene flame. Eight hundred milligrammes of dried potato sample were weighed into digestion tubes and 8 ml of HNO_3 Suprapure (Merck) added. The mixture was heated in 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 to room temperature, 0.5 ml of HCl Suprapure (Merck) were added and it was heated to 170 °C/S mm. Then, this solution was quantitatively transferred and adjusted to 10 ml with ultra pure water. For the determination of Na, K, Ca and Mg it was necessary to make a new dilution, taking 1 ml of the concentrated solution and adjusting to 10 ml with ultra pure water. Ca, Mg, Fe, Cu, Zn and Mn were determined by atomic absorption spectrometry, and Na, K and Rb were determined by atomic emission spectrometry using the instrumental conditions recommended.

2.3. Quality control

Wheat Flour Reference Material (ARC/CL3, LGC Deselaers) was used for metals, except for Mn and Rb. Quality controls for both metals (Mn and Rb) were checked using potato samples spiked and not spiked with known amounts of Mn and Rb standards. The percent of recoveries and percent of standard deviations are given in Table 2. The percent of recovery ranged from 98.5 to 102%. Coefficients of variation were always $<5\%$, ranging between 2.9 and 4.8%. The contents of

Table 2
Recoveries obtained for the determination of metals

Metal	Recommended value (mg/l)	Found value	Percentage of recovery	C.V. (%)
Na	3200	3155±104 ($n=10$)	98.6±3.3	4.1
K	158	159±4.8 ($n=9$)	100.7±3.1	3.1
Ca	89	88.7±3.5 ($n=8$)	99.7±3.9	3.9
Mg	20	19.8±0.66 ($n=9$)	99.1±3.3	3.3
Fe	1.1	1.08±0.03 ($n=8$)	98.0±13.1	4.8
Cu	1.3	1.28±0.04 ($n=9$)	98.4±2.7	4.0
Zn	1.48	1.50±0.05 ($n=8$)	101±3.8	4.9
Mn	0.620[a]	0.637±0.01 ($n=6$)	103±3.2	4.1
Rb	0.480[a]	0.487±0.008 ($n=6$)	98.6±2.6	2.9

[a] Amounts spiked.

the metals in the potato samples were clearly higher than the detection and the determination limits observed. Therefore, the determinations are sufficiently accurate, precise and safe.

2.4. Statistics

All statistical analyses were performed by means of the SPSS version 10.0 software for Windows. The Kolmogorov–Smirnov's test was applied to verify whether 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 from extraction of factors, was used to summarize the information in a reduced number of factors. Cluster analysis was used to search the natural groupings among the samples. The sample similarities were calculated on the basis of the squared Euclidean distance, and the Ward method was used to establish clusters.

3. Results and discussion

Fig. 1 shows the mean concentrations and standard deviations of the metals analyzed for the traditional potatoes and recently imported potatoes. In general, the mineral contents in traditional potatoes were higher than those mineral contents found in recently imported potatoes. Only the contents of Na and Mg were higher in recently imported potatoes. Also, the ratio Na/K, calculated for the recently imported potatoes, was clearly higher that that ratio observed for traditional potatoes. This point seems important, since some mechanistic and epidemiological data suggest that the Na/K status may be related to increase of blood pressure and cardiovascular diseases (Krummel, 2001). Therefore, the consumption of traditional potatoes is advantageous in relation to these diseases. Important differences ($P<0.050$) were observed between the contents of K, Fe, Cu and Zn, with higher values for the traditional potatoes. The levels obtained in this work are in the same range of those reported by other authors for potatoes from several countries, such as Holland (Van Marle, Van Dijk, Voragen, & Biekman, 1994), Canada and the USA (Anderson et al., 1999) and Jordan (Ereifej, 1998; Nabila et al., 1998) and in international food composition tables (Schertz & Senser, 2000; US Department of Agricultural, Agricultural Research Service, 1999). Also, our data agree with those published in other Spanish regions, such as Galicia (Padín et al., 2001).

The results for the analyzed metals grouping the potato samples in the eight cultivars and as a function of species/subspecies are presented in Table 3. The results of one-way ANOVA for comparison are also included in this table. No significant differences ($P>0.05$) were found among the mean concentrations of the eight cultivars considered for Ca, Mg and Fe. However, there are several metals that allow discrimination among cultivars. The mean concentrations of K in the cultivars Palmera and Cara were significantly ($P<0.050$) lower than the mean concentrations obtained in the rest of cultivars. In contrast, the cultivars Cara and Negra presented the highest ($P<0.050$) mean concentrations for Na. In relation to the alkaline-earth metals, the mean contents in the analyzed

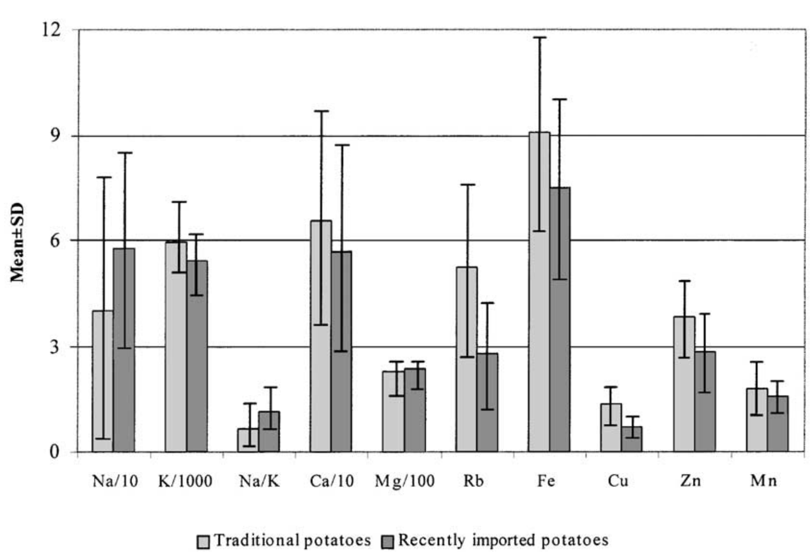


Fig. 1. Mean concentrations of the analyzed metal for traditional potatoes and recently imported potatoes.

Table 3
Metal average concentrations (mg/kg) for the different types of potatoes studied[a]

Specie/ subspecie	Cultivar	Na	K	Na/K×100	Ca	Mg	Rb	Fe	Cu	Zn	Mn
S. andigena	Bonita	36.7±36.2ab	6519±919cd	0.55±0.48ab	6l.1±20.6ab	221±38.6ab	5.94±1.36cd	8.25±1.95abc	1.54±0.39b	3.64±0.60bcd	2.11±0.84b
	(*n*=16)	(9.7–136)	(5209–7991)	(0.18–1.85)	(29.9–96.9)	(154–284)	(3.63–8.39)	(5.71–12.82)	(0.92–2.22)	(2.80–4.84)	(0.73–3.62)
	Colorada	31.2±17.8ab	5969+634bc	054±035ab	47.6±24.8a	188±53a	6.84±4.19d	8.58±2.86abc	0.92±0.46a	2.91±058ab	2.14±0.83b
	(*n*=9)	(11.5–60.1)	(4719–6837)	(0.18–1.27)	(15.7–89.1)	(113–275)	(1.05–14.7)	(5.35–14.54)	(0.29–1.59)	(2.03–3.90)	(0.54–3.20)
	Azucena	22.3±7.2a	6938±791d	0.32±0.11a	81.0±25.0ab	250±33.9b	6.96±1.27d	11.2±1.25c	2.12±0.36c	5.12±0.76e	1.81±0.43ab
	(*n*=5)	(15.1–33.4)	(5702–7623)	(0.20–0.46)	(53.9–114)	(217–287)	(5.48–8.36)	(9.56–12.4)	(1.91–2.75)	(4.33–6.36)	(1.12–2.22)
S. tuberosum	Palmera	17.1±33.4a	4910±459a	0.35±0.04a	76.4±37.2ab	221±57.9ab	5.01±0.34bcd	10.4±2.91bc	1.71±0.40b	4.34±1.11cde	1.74±0.83ab
	(*n*=6)		(4519–5723)	(0.30–0.42)	(42.6–127)	(169–310)	(4.56–5.35)	(7.11–13.8)	(1.27–2.15)	(2.30–5.41)	(0.762.83)
	Peluca	377±42.5ab	5818±1556bc	O.59±0.50ab	87.3±39.7b	246.2±68.5b	4.51 ±2.33abc	9.37±3.46abc	1.72±0.36b	4.58±0.86de	1. 77±0.67ab
	(*n*=6)	(11.3–122)	(4511–8234)	(0.21–1.48)	(40.6–145.0)	(168–359)	(1.13–8.04)	(5.86–15.5)	(1.20–2.29)	(3.35–5.60)	(1.04–2.70)
	Cara	66.6±32.1b	4890±814a	1.39±0.68c	63.6±34.5ab	228±45.4ab	3.12±1.65ab	7.19±3.13a	0.54±0.27a	2.18±0.79a	1.43±0.49ab
	(*n*=10)	(23.2–118)	(3526–5988)	(0.44–2.49)	(25.1–119)	(141.9–291)	(0.86–5.59)	(4.03–14.1)	(0.23–1.13)	(0.78–3.25)	(0.792.13)
	Rosada	49.1±22±7ab	5989+578bc	0.85±0.47abc	50.6±25.5a	2450±38.8b	2.51±1.55a	7.78±2.07ab	0.88±0.30a	3.52±1.12bc	1.68+0.49ab
	(*n*=10)	(25.6–89.4)	(5215–7038)	(0.36±1.56)	(26.2±105)	(182–297)	(0.90–5.23)	(4.94–11.5)	(0.49–1.35)	(1.76–5.21)	(1.02–2.74)
S.×chaucha	Negra	66.1±48.9b	5505±425ab	1.13±0.86bc	64.5±35.7	233±28.1b	33.4±1.73ab	8.96±3.58abc	0.89±0.43a	37.0±143bcd	1.19±0.44a
	(*n*=15)	(21.2–176)	(4523–6198)	(0.37–3.15)	(21.6–147)	(188–298)	(1.19–6.97)	(5.14–17.3)	(0.47–1.68)	(1.89–7.21)	(0.75–2.26)

[a] Results in the same column with the same letter were not significantly ($P<0.05$).

cultivars did not show statistical differences. The mean Ca concentrations varied between 47.6 mg/kg, obtained for the cultivar Colorada, to 87.3 mg/kg, found for the cultivar Peluca. A lower variation in the mean contents among the cultivars was observed for Mg, ranging from 188 mg/kg in Colorada and 250 mg/kg in Azucena. The behaviour of trace elements was very interesting, with the highest mean concentrations of Fe, Zn and Cu in Azucena, Palmera and Peluca, and the lowest concentrations in Cara. The mean content of Cu in the cultivar Azucena were higher ($P<0.05$) than those mean contents found in the cultivars Peluca, Palmera and Bonita and these were higher ($P<0.05$) than the contents observed in the Colorada, Negra, Rosada and Cara. The mean contents of Mn in the cultivars Colorada and Bonita were higher than in the rest of cultivars.

The double logarithmic matrix correlation (Table 4) indicates associations between pairs of measured variables. Many significant ($P<0.05$) correlations were observed. The trace elements considered (Fe, Cu, Zn and Mn) showed significant correlation with all the metals studied. The alkaline-earth metals (Ca and Mg) and K presented significant correlation with all the metals except Na. Most of the correlations were positive which indicates that, when the concentration of a metal increases, the concentrations of other metals also increase. However, correlations observed between Na and Rb, Fe, Cu, Zn and Mn were negative. Probably, the influence and precipitation of marine aerosol in the cropping soils could affect the bioavailability and uptake, by the plants, of the metals from the soils. Among the correlations defined, the following correlations: Cu–Zn, Fe–Zn, Mg–Zn and Ca–Fe were noteworthy, because of their relatively high correlation coefficients ($r>0.5$). These correlations define the following regression lines:

LogCu–LogZn	LogCu = −0.564 + 1.094 LogZn	$r=0.754$
LogFe–LogZn	LogFe = 0.695 + 0.420 LogZn	$r=0.504$
LogMg–LogZn	LogMg = 2.196 + 0.294 LogZn	$r=0.510$
LogCa–LogFe	LogCa = 1.018 + 0.802 LogFe	$r=0.516$

Factor analysis was applied to all the samples of potato studied to obtain a more simplified view of the

Table 4
Double logarithmic matrix correlation for all the samples (when $P>0.05$ values are not shown in table)

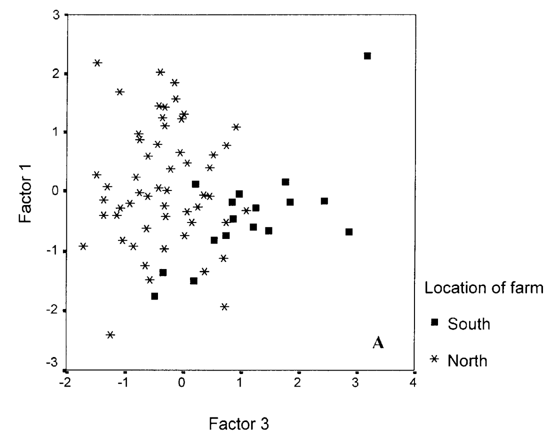
	LogNa	LogK	LogCa	LogMg	LogRb	LogFe	LogCu	LogZn	LogMn
LogNa					−0.490	−0.298	−0.461	−0.237	−0.361
LogK			0.242[a]	0.460	0.254	0.340	0.395	0.466	0.450
LogCa				0.371		0.516	0.345	0.316	0.283
LogMg						0.330		0.510	0.290
LogRb							0.459		0.292
LogFe							0.397	0.504	0.354
LogCu								0.721	0.327
LogZn									0.261

[a] Coefficient correlation of Pearson.

relationship among the metals considered. The first three factors were selected (70.4% of the total variance) because their eigenvalues were higher than 1 and therefore, they explain more variance than the original variables (Ferrán, 1996). All the metallic variables, except Ca, presented a communality higher than 0.6 and therefore they are well represented by these three factors. A-Varimax rotation was carried out to minimize the number of variables that influence each factor and then facilitate the interpretation of the results (Table 5). The first factor that explains the higher percentage of variance (39.9%) is mainly related to Zn. The second factor is related to the Mn and K; the third factor is negatively related to Na. The scores plot for all the potato samples of the representation of the second and third factor is shown in Fig. 2. It can be observed that the potato samples belonging to the species *S.×chaucha,* with negative scores in factor 2, tend to separate from the ssp. *andígena* (positive scores in the factor 2), while the potato samples of ssp. *tuberosum* were nearer to the potato samples *S.×chaucha* than the potato samples of ssp. a*ndígena*. Moreover, the potato samples tend to separate according to the location of farms (North and South of the island) and to the irrigation procedure used (irrigation and non-irrigation) when the factors 1 and 3 are represented (Fig. 3A and B). Consequently, one can deduce that metallic contents in the potato samples are strongly influenced by the metallic contents of the

Table 5
Factor matrix obtained after a Varimax rotation

Mineral	Factor		
	1	2	3
Zn (mg/kg)	**0.848**	0.130	0.100
Fe (mg/kg)	0.711	0.273	0.159
Cu (mg/kg)	0.676	0.165	0.530
Ca (mg/kg)	0.674	0.084	−0.045
Mg (mg/kg)	0.582	0.369	−0.562
Mn (mg/kg)	0.174	**0.799**	0.242
K (mg/kg)	0.346	**0.792**	−0.163
Na (mg/kg)	−0.209	−0.078	**−0.820**
Rb (mg/kg)	−0.040	0.598	0.620



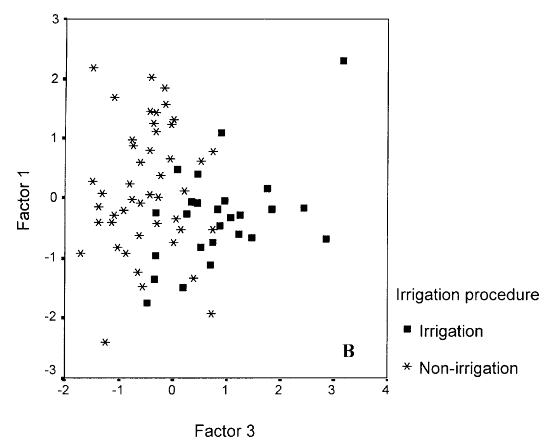


Fig. 3. Scores of the potato samples on axes representing factor 1 and factor 3, differentiating by location of farms (A) and by irrigation procedure used (B).

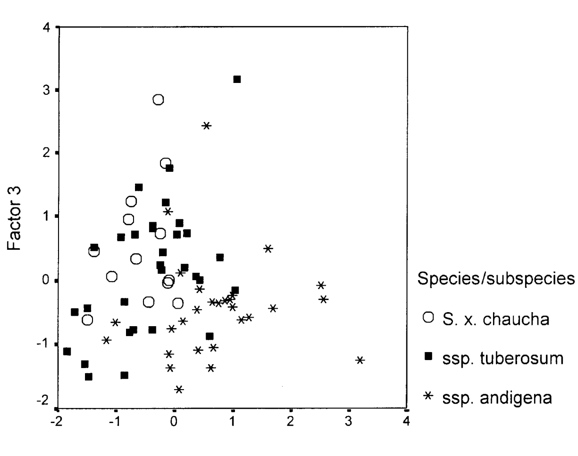


Fig. 2. Scores of the potato samples on axes representing second and third factors differentiating by species or subspecies.

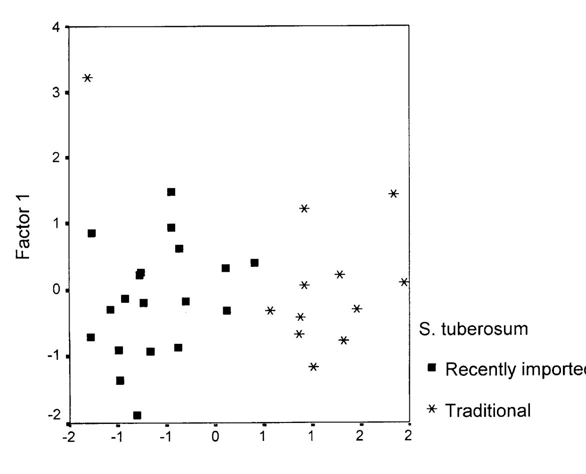


Fig. 4. Scores of the potato samples belonging to *S. tuberosum* on axes representing the two factors differentiating by cultivar.

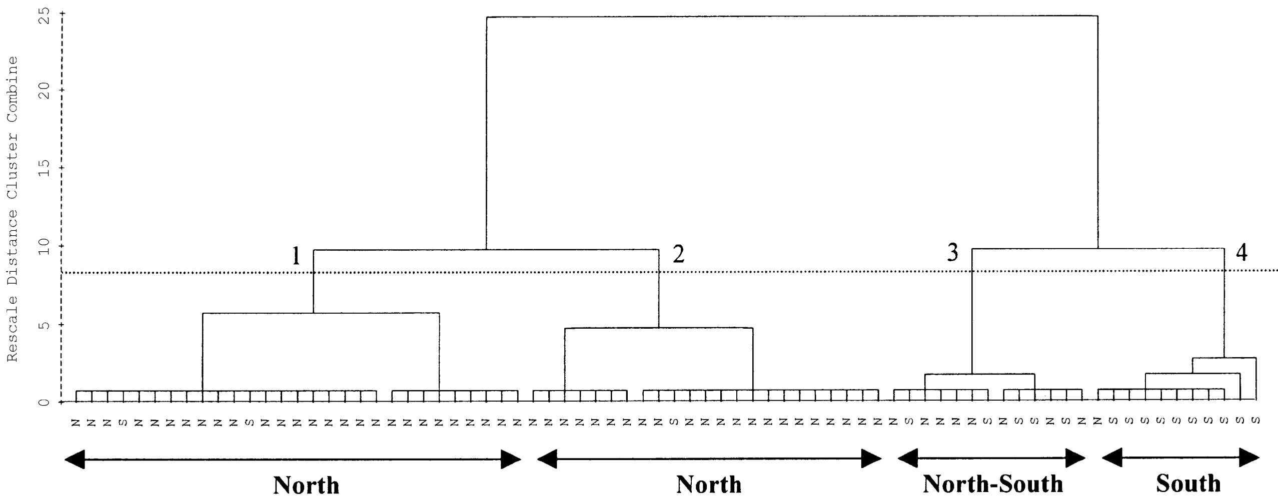


Fig. 5. Dendrogram of the cluster analysis.

cropping soils and the metallic contents of the water for irrigation. Therefore, the influence of sample taxonomic groups and cultivars seems to be less important than environment.

Applying factor analysis to the samples of potatoes belonging to the species *S. tuberosum*, two factors were extracted which explained 63.5% of the total variance. Representing the scores of the potato samples by these two factors, samples of the cultivars Palmera and Peluca, which belong to the group of traditional potatoes, were well separated from the samples of the cultivars Cara and Rosada included in the group of recently imported potatoes (Fig. 4). This suggests that the cultivars of potatoes harvested in the Canary Islands can change their characteristics.

The results obtained in the cluster analysis are presented as a dendrogram in Fig. 5. The variables used for this study were Zn, Mn and Na, variables that presented higher correlations with the three first factors in the factorial analysis. Considering a distance of 8, four clusters can be identified as follows: the first cluster (1) is composed of 29 samples; the second cluster (2) contains 23 samples; the third cluster (3) includes 13 samples and the fourth cluster (4) is formed by 11 samples. The first two clusters correspond to potato samples located in the north of the island with exception of two and one samples, respectively; the fourth cluster is associated with samples from south of the island, and the third cluster is a mix of north and south samples. Therefore, a tendency to classify the potato samples as a function of the location was observed, which agrees with the results of factor analysis.

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