Effect of Genotype and Geographical Origin on Potato Properties (Physical and Sensory) for Authenticity Purposes

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Abstract

This study was undertaken to determine the physicochemical and sensory characteristics of two potato cultivars (Spunta and Agria), cultivated in three geographical regions of Greece (Macedonia, Thessaly, Peloponnese). Multivariate analysis was applied to reveal relationships among various parameters and the effect of genotype and cultivated region. PCA showed specific sensory profile for the fresh tubers strongly depending on the potato cultivar. Similarly, implementation of PCA to the boiled potato tubers revealed concrete sensory profile for the geographical origin. The (CA) effectively grouped the physicochemical attributes, minerals and the sensory attributes related to taste, colour and odour. Application of (DA) both for cultivars and geographical regions disclosed that the most important parameters describing the overall acceptability were sweet taste, special taste and aftertaste persistence. In conclusion, the obtained information regarding the effect and interaction of cultivar and geographical region on potatoes quality could be potentially exploited for authenticity purposes.

Keywords: *Solanum tuberosum*, Physicochemical analysis, Sensory analysis, Multivariate analysis, Geographical origin, Potato cultivars

1. Introduction

Vegetables are considered one of the most important foods of the European diet, and are traditionally served alongside a protein (e.g. meat, fish) or a carbohydrate food (e.g. pasta, rice, potato) Vegetables provide textural and colour variety to the meal and, more importantly, complementary nutrients such as dietary fibre, vitamins, minerals, folate (Favell, 1998) and flavonoids with beneficial cardiovascular activity (Chiu & Fung, 1997). The potato (*Solanum tuberosum* L.) is a staple component of the diet in many human cultures and source of many essential nutrients. It is available all year round and may be cooked with various means (e.g. boiling, baking, and frying) prior to consumption (Oruna-Concha et al, 2000). European integration has considerably changed the market, paving new avenues for competition, especially in the potato industries of the most recent members of the EU. This has increased the demand for a comprehensive understanding of potato's quality, thus requiring recognition of the factors affecting the characteristics of the end product. Moreover, it may not be clear which properties or factors should be measured to predict the storage tolerance, process behaviour and the resulting total quality of the end product (Vainionpaa et al, 2000).

There are various factors contributing to the quality of potato determined with numerous sensorially and instrumentally measured variables. Consequently, the quality can be defined with a complex matrix of intercorrelated factors that cannot be comprehensively analysed by means of traditional methods. Some factors affecting the potato's tuber quality, are pulp pH, total acidity, and starch content. The pH index determines the deterioration potential due to fermentation and enzymatic activity. The phosphorylase acts predominantly on starch breakdown with maximal activity at pH 5.5 (Iritani & Weller, 1973). Invertase, on the other hand, promotes sucrose breakdown into glucose and fructose, and shows an optimal point at pH 4.7. Furthermore, pulp pH varies and displays a negative correlation (-0.86) with reducing sugars accumulation. The total acidity parameter quantifies organic acids present in foods and displays a tendency of reduction in their contents because of respiration and/or due to conversion into sugars, which could contribute toward browning of the fried product due to acrylamide formation (Feltran et al, 2004). Moreover, texture is very important for the consumer's perception of potato quality. Consumer texture preference of cooked potatoes varies according to age, both within and between countries and is highly dependent on processing, confirming the need for sensory texture characterisation of cooked potatoes. Methods for measurement of the sensory texture profile of cooked potatoes have been developed and validated in several studies, thereby grouping the textural profile into mechanical, geometrical and moisture dimensions (Thybo et al., 2000).

Textural qualities of potatoes are described both by the starch content in the cells and the cell wall components. High contents of pectins, bivalent ions (Mg, Ca), high activity of pectin methyl-esterase and low content of monovalent ions (K, Na) and organic acids (citric and phytic acid) were attributed to favour the formation of pectic bonds among cells. These chemical characteristics are thus expected to be associated with high adhesion between cells, high firmness/hardness and low mealiness (Thygesen et al., 2001). Moreover, the dry matter content (of which 60-80% is starch) was reported to be highly associated with the texture of cooked potatoes (McComber et al., 1994). Nevertheless, only very few references regarding correlation between dry matter content and texture attributes are available in the literature (Cess van Dijk et al., 2002).

Fatty acids, sugars, and amino acids are the precursors of most of the compounds responsible for the flavour formed in potato tubers baking. The products of thermal degradation of fatty acids include various aldehydes and ketones, which may impart fatty, fruity, or floral notes. The Maillard reaction, involving reducing sugars and amino acids, results in a wide range of compounds including various pyrazines considered to be key components of baked potato flavour. Strecker degradation of the amino acid methionine yields methional, which has a potato-like odour and is another important contributor to baked potato flavour. There are reports of intercultural differences in levels of flavour compounds and in perceived aroma of boiled potatoes. The levels of flavour compounds of baked potato flesh were also reported to vary considerably among cultivars (Duckham et al., 2002). However, most investigations of the relationship between chemical composition and texture of cooked potato have utilised field-grown material Subjectively, measured textural differences, between cultivars and between tubers from different growing areas, have been related to differences in the chemistry of tubers. Under these circumstances, although differences in texture are often found, there are usually quite large differences in the levels of all the constituents considered to be of importance in affecting the texture (Arvanitoyannis et al 2008). Furthermore, texture assessed considerably depends on the interaction within a number of physical characteristics and a number of different chemical constituents. It is therefore difficult to demonstrate a causal relationship between texture and the level of any individual chemical constituent (Linehan & Hughes, 1969).

The purpose of the current work was to study the physicochemical and sensory properties of different potato cultivars coming from three different geographic regions of Greece, and to correlate the results of fresh and boiled potato values with cultivars and geographical origin. The importance of this study resides in the high variation in chemical composition and sensory properties found in potatoes grown in Greece.

2. Materials and Methods

2.1 Potato Cultivars

The two cultivars tested, were Spunta (Oldenburger, Assem, Holland) and Agria (Kartoffelzucht, Bohm, Germany). The potatoes were cultivated in three regions of Greece, (Macedonia - North Greece, Thessaly – Central Greece and South Greece –Peloponnese). To be more specific the regions were: Nevrokopi (Makedonia - North Greece), Karditsa (Thessaly - Central Greece), Corinthus and Tripoli (Peloponnese - South Greece). The sampling from the two cultivars of potato took place progressively. Actually, the tubers from cultivar Spunta characterized by earliness, were harvested in July 2008 in the region of Thessaly, followed by samples of the same cultivar, from the region of South Greece harvested by the end of July 2008. The sampling of cultivar Agria from the region of Thessaly was carried out in August 2008. The samples of cultivars Spunta and Agria from North Greece, were dispatched in the beginning of September 2006. Finally, sampling of cultivar Agria from the region of South Greece was conducted in October 2006. Table 1 gives the coding per region of origin used over the experiment. The numbers 1, 2 and 3 indicate the cultivars corresponding to the regions of sample origin, that is; Macedonia, Thessaly, and Peloponnese, respectively.

2.2 Regional Characteristics

Some of the most important characteristics of the soils, where the two cultivars of potato come from, are given in Table 1. The soil analyses revealed that, soil composition according to soil type was the same for each cultivar irrespectively of cultivated region. The pH varied within the range 5.1 and 7.6. The determined organic matter (OM) values were similar for the first two regions (Macedonia and Thessaly) except for the area of Peloponnese where the OM of fields where Agria was cultivated, differed considerably (Table 1). The soil composition according to macro elements can be grouped dually in most cases. However, it was noteworthy that most substantial differences were recorded for Potassium and Nitrogen in the regions of Macedonia and Thessaly, respectively. This observation is important when comparing potato samples from completely different culture environments (organic versus conventional) (Gilsenan et al., 2010).

2.3 Physico-chemical Properties

2.3.1 Firmness

Firmness was measured using a manually operated penetrometer (Fruit tester FT 327 Effegi, 48011, Alfonsine, Italy, unit of measurement: kg) of a probe diameter of 0.5 cm and insertion depth of 1.5 cm (Harker et al., 1997; Johnston et al., 2001). The samples, consisting of five tubers per cultivar and region, were peeled, washed off and left to dry. A minimum of twenty penetration measurements per tuber was carried out.

2.3.2 pH and Total Acidity

A digital pH meter was used for taking pH measurements. Juice from tubers (4 g) was mixed with water (20 g) and the electrode was dipped into the solution. The value was recorded after instrument calibration. Determination of total acidity was carried out with volumetric analysis of the solution with NaOH 0.1N until the pH was 8.3. The percentage concentration of maleic acid (%) (main acid in potato) was determined with titration with sodium hydroxide and calculated by multiplying the obtained value with the conversion coefficient 0.067.

2.3.3 Dry Matter

Samples of peeled tubers, weighing 100 g per experimental treatment were cut in thin slices and drained in oven at 97ºC for 24h. Following drying the exact weight of sample was recorded. Determination of dry matter (%) was conducted as a result of weight loss of samples. Five replicates were analysed per experimental treatment.

2.3.4 Minerals K, N, P and Metals Cu, Zn, Mn, Fe

Tuber samples were analysed for PO_4^{-3} with ion chromatography, while the total nitrogen was determined with Kjehdahl. The K^+ ions were measured both with methods of flamephotometry (with flamephotometer Sherwood) and ion chromatography. Finally, minerals were determined by means of atomic absorption spectroscopy (Perkin Elmer 3300).

2.4 Sensory Analysis

Sensory analysis was carried out on the basis of questionnaire results (Montouto-Graña et al., 2002). A testing panel (10 panelists, trained on various taste and flavour attributes) filled the questionnaires according to ISO 8586:2008. All sensory analysis sessions were carried out in a test room set up according to ISO 8589:2007. For analysis of sensory characteristics of the raw product, each assessor received five to six raw potatoes (pending on size). The questionnaires had a five-grade scale per attribute; very intense, intense, medium, a little intense, no intense. For the sensory test of cooked potato, six to eight potatoes were boiled for 45 min and placed in plastic numbered plates and immediately assessed. Water and bread were provided for cleaning and rinsing the palate between samples. The sensory parameters for the fresh tubers of potato were, skin colour, skin brightness, internal colour, surface roughness, odour intensity, moistness, surface wrinkling and stains while the sensory characteristics measured for the boiled tubers of potato were odour intensity, moistness, special taste, sweet taste, aftertaste persistence, metal taste, pastiness, mastication, flavour intensity, elasticity and overall acceptability.

2.5 Statistical Analysis

The results were analysed for ANOVA with SPSS 14.0 (Statistical Package for Social Sciences, Chicago, IL, USA). Principal Component Analysis (PCA), Discriminate Analysis and Cluster Analysis were employed towards revealing correlations between sensory and instrumental data with JMP 5.1 (SAS, USA).

3. Results and Discussion

The results from ANOVA disclosed significant differences mainly among the regions and, to a lesser extent, between the two cultivars. Agria had the highest pH (6.23) whereas Spunta displayed the highest total acidity (pH:6.08) with 0.14% maleic acid (Table 2). The tubers of cultivar Agria were found to be more cohesive (78.87 Nt) than Spunta (68.24 Nt). Firmness constitutes a characteristic trait of genetic material (Thybo et al., 2000), that justifies the attribute’s stability of the two investigatedcultivars independently from their region of origin. The average dry matter percentage of potato tuber amounted to 23.27%, confirming the absence of differences between cultivars. However, the ANOVA revealed important differences among the tubers of different geographical origin for the rest of physical properties. The dry matter content of potato usually ranges from 18 up to 26% (Burton, 1989) and is incredibly important parameter of potato quality, as it influences the effect of cooking on sensory attributes (Taylor et al., 2007). The sensory characteristics of fresh potatoes of the two cultivars presented significant statistical differences between skin colour, internal colour, surface roughness, and surface staining (Table 3). On the contrary, important statistical differences were not recorded in skin brightness, surface wrinkling, moisture content and odour intensity. Skin colour of Spunta was evaluated on average with 4.21 while the variety Agria with 6.44 (Scale 1-9, 1= light beige, 9= dark brown). These data agree with the established phenotype of cultivars. According to European Cultivated Potato Database, the cultivar Spunta is described with white colour of skin while Agria with yellow (http://www.europotato.org). Similar results are also reported for the internal colour, evaluated with 4.24 and 6.44 for Spunta and Agria, respectively. With regard to the presence of stains, the cultivar Spunta displayed the less, with evaluation 3.47 and Agria with 4.90 (Table 3). Presence of stains and /or alteration on potato skin of Agria may be due to its higher sensitivity toward biotic and abiotic stresses than Spunta. The statistical differences recorded for all sensory characteristics apart from odour intensity, could be attributed to geographical origin of the two cultivars. The sensory characteristics of boiled potatoes of two cultivars following the analysis of variance revealed important statistical differences (Table 4) are the following: odour intensity, special taste (particular taste referring to a combination of taste and odour), sweet taste (although this characteristic was not differentiated among regions), aftertaste persistence residual taste and flavour in the mouth of panellists following the elapse of certain seconds), and overall acceptability.

Moreover, statistical differences were recorded among different regions for most sensory attributes [odour intensity, moistness (how the testers felt while tasting potato), special taste, aftertaste persistence, metallic taste, flavour intensity, mastication, elasticity and overall acceptability] except for sweet taste and pastiness. To be more specific, Spunta was evaluated with 4.65 for odour intensity whereas Agria with 5.15 (Table 4). For the same characteristic, however the region of Northern Greece (Nevrokopi) and the region of Thessaly (Karditsa) did not differ considerably, while the region of South Greece was evaluated with the highest odour intensity, 5.22. The same is applicable to moistness, the values of which were 4.84 and 5.20 for Spunta and Agria, respectively. Sweetness assessment of the cultivars Spunta and Agria amounted to 4.05 and 6.52, respectively. This trait characterised the cultivar Agria, since it has high sugar concentration (glucose, fructose and sucrose) (Amrein et al., 2003).

The chemical constitution of fresh potato tubers revealed significant differences between the two investigated cultivars and the geographical origin (Table 5). However, the interactions between the cultivars and the geographical origin also disclosed important statistical differences. The content of potato tubers in potassium (K) of cultivar Spunta, was 181.77mg/Kg of tuber's dry weight, of nitrogen (N) 94.13 mg/Kg, of phosphorus (P) 80.49 mg/Kg, of copper (Cu) 4.65 mg/Kg, zinc (Zn) 5.91 mg/Kg, manganese (Mg) 31.00 mg/Kg and iron (Fe) 32.29 mg/Kg. The concentration for all chemical elements of Agria was higher than Spunta, apart from nitrogen (Table 5). The chemical composition of potatoes with regard to geographical origin for potassium, nitrogen and phosphorus, (the three main components of fertilizers), are found in higher concentrations in the region of South Greece, 250.72mg/kg, 89.26 mg/kg and 145.12 mg/kg, respectively. The determined differences in determined mineral content may be also attributed to different fertilisation regimes applied per region. For example, the region of Thessally had the greatest concentration in minerals.

3.1 Principal Component Analysis (PCA)

In the case of physicochemical characteristics, the first principal component (PC1) explains 54.34% of total variance, PC2 42.56% and PC3 1.88%. There was no explicit grouping of physicochemical characteristics for any of the two cultivars (Spunta or Agria). In the figures of principal component analysis the first letters referred to the potato cultivar (Agr. = Agria, Sp. = Spunta) while the numbers allocated by the end of code to the region of origin (1= North Greece, 2= Central Greece και 3= South Greece). The used abbreviations for the sensory characteristics are given in Table 6. Application of PCA, for mineral content (Cu, Zn, Mn and Fe) resulted in concrete groups thereby confirming both the effect of cultivar and the effect of geographical origin (Figure 1). PC1 explains 59.83% of total variance and PC2 40.17%. In Figure 1, in the first quadrant (A), the three out of the four measured minerals of the cultivar Spunta are grouped while the same grouping was observed in the third quadrant (D). The latter included the minerals occurring in region 1 (North Greece). The three principal components of PCA for sensory characteristics of fresh potato tubers explained 45.41% of total variance (Figure 2). The effect of cultivar shown in all groups of principal component analysis was clearly perceptible. In the first and third quadrants there are three clusters (A, B, D) grouping sensory characteristics according to cultivars; (A) for Spunta, (B) and (D) for Agria. On the other hand, there are three clusters which group sensory properties per region of origin: (C) for Macedonia and Thessaly, and (E) & (F) for Peloponnese. For this region of South Greece (3) both for cultivars Spunta and Agria, were described by odour intensity, moisture, skin brightness and skin colour. Our texture –related sensory attributes are in satisfactory agreement with the findings of PCA and PLSR on cooked potato reported by Povlsen et al. (2003).

3.2 Cluster Analysis (CA)

Groupings based on Cluster Analysis for physicochemical and sensory characteristics and the effect of potato cultivar and geographical origin are shown in Figures 3 & 4.

Figure 3 displays the clustering of parameters based on the geographical origin. The first cluster (A) consists of firmness and the contents of nitrogen, potassium, phosphorus, manganese and iron. Moreover, the connection of firmness with the concentrations of macro elements (N, K, P) was established similarly to manganese and iron. The latter are required, in appropriate concentrations, for the production of structural components of proteins that constitute the foundations for the regular increase and development of plants (Sinha et al., 2006). The second cluster (B) included all the sensory characteristics, both for fresh and boiled tubers, the total acidity, pH, the dry matter and the content in Cu and Zn. The presence of dry matter and two minerals in the particular cluster implies their relation with the sensory profile of the tubers that originated from the three under study regions. Moreover, the percentage of dry mater, as shown in the analysis of variance, varies from one region to another whereas the concentrations of metals constitute characteristic trait of regions (Sinha et al., 2006). Figure 4 displays the five groupings of the characteristics for potato tubers based on the effect of cultivar. In the first cluster (A) the physicochemical characteristics of fresh tubers like firmness and the concentrations of nitrogen, potassium, phosphorus, manganese and iron are included. These characteristics are reasonably related, because they are required for the shaping of tubers and their normal growth. The second cluster includes all the sensory characteristics both for fresh tubers and boiled. However, this cluster also comprises five physicochemical characteristics of tubers; pH, total acidity, dry matter and the concentrations of copper and zinc. It is noteworthy that pH, total acidity and dry matter of vegetables are directly related to their sensory constitution (Casanas et al, 2002). The third in line subcluster (C), included the odour intensity, the surface wrinkling of fresh tubers, the stains of fresh tubers, the metal taste of boiled tubers, flavour intensity of boiled tubers, mastication, την pastiness, elasticity and the total acidity of tubers. The fourth and fifth subcluster (D και E) included the rest of sensory characteristics and certain physicochemical such as the concentrations of copper and zinc, and pH. The cluster analyses shown in Figures 4 & 5 revealed the presence of three grouping patterns (P_1, P_2 & P_3). To be more specific, P_1 groups the physicochemical attributes (firmness, N, K, P, Mn, Fe), P_2 (elasticity & total acidity) and P_3 the sensory attributes related to taste, colour and odour. These grouping patterns are the same both for cultivars and geographical origin thereby confirming the presence of a strong relationship among the attributes grouped.

3.3 Discriminant Analysis (DA)

The Discriminant functions produced by the sensory characteristics of boiled potato tubers of the two cultivars originating from three geographical regions, are summarised in Table 7. In general, the overall acceptability of boiled tubers is dependent upon the remaining ten characteristics (odour intensity, moistness, special taste, aftertaste persistence, metallic taste, pastiness, mastication, flavour intensity, elasticity and sweet taste). The percentage of variance explaining the discriminant functions varies within the range 72% to 96%. In most cases, the equations that present the cross-correlation of overall acceptability of boiled tubers of the two potato cultivars do not include the total of ten attributes. The explanation to the latter is that the objective of discriminant analysis is to interpret the highest possible amount of original variance and not the presence of all attributes in the derived equation. For the cultivar Spunta of Nothern Greece (1), the attributes that had the greatest impact on overall acceptability, are sweet taste (positive) and special taste (negative). For the same cultivar from the region of Thessaly (2), attributes like flavour intensity and sweet taste greatly determined the overall acceptability. Finally, for Spunta from South Greece (3) the parameters displaying the highest relative weight on overall acceptability were odour intensity (positive) and aftertaste persistence (negative). In our case the overall acceptability of Agria cultivar, coming from North Greece, is explained, with a rate of variance 96%, by means of parameters like moistness, special taste and sweet taste. Among these parameters, the moistness and the sweet taste appear to have the strongest effect. For the cultivar Agria originated from Thessaly, aftertaste persistence and moistness explained 89% of total variance, while from South Greece, overall acceptability was found to be dependent upon special taste and sweet taste. Summarizing the above mentioned findings with DA, it is important to notice that the overall acceptability for the cultivar Agria was described only by two or three attributes whereas for Spunta, a greater number of attributes, was required (4-10) (Table 7).

4. Conclusions

The Analysis of Variance (ANOVA), revealed statistically significant differences ($p \leq 0.05$) between the determined physicochemical and sensory parameters, based on the effect of cultivar and geographical origin. The effect of cultivar is significant for all physicochemical characteristics apart from total acidity and content of dry matter. The cultivar Spunta produces tubers with higher acidity against the cultivar Agria, while the latter is more cohesive than Spunta. The geographical origin of cultivar is of great importance to physicochemical characteristics apart from firmness. Tubers originating from South Greece have the highest acidity while the potatoes from North Greece and the Central Greece are characterized by high dry matter. The analysis of chemical composition revealed that in South Greece the tubers had the highest content in elements like N, K and P while the tubers grown in the region of Thessaly had the highest concentration in metals (Cu, Mn, Zn και Fe). Principal Component Analysis applied to minerals, did reveal concrete groupings both for cultivar and region. The sensory characteristics of fresh tubers are separated based on cultivars while the sensory characteristics of boiled tubers were effectively separated both based on cultivar and geographical origin. Cluster Analysis on the other hand, displayed grouping of all sensory characteristics for the potato cultivars and the geographical region of origin. Moreover, this particular analysis combined the sensory parameters of potato tubers with certain physicochemical characteristics. The application of Discriminant Analysis for the two cultivars and three geographical regions revealed that the parameters most frequently affecting the overall acceptability of boiled potato tubers are sweet taste, special taste and aftertaste persistence. Furthermore, cv. Agria required only 2-3 sensorial attributes for describing overall acceptability whereas for Spunta the corresponding number was much higher. Finally, the main conclusion of this research is that discrimination of potatoes with regard to cultivars and geographical region is possible either based on mineral or sensory analysis in conjunction with multivariate analysis (PCA, CA, DA). Therefore, the above findings could be further exploited for potato/food authenticity purposes.

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Table 1. Coding of potato cultivars based on geographical origin and soil types

Code No of potato cultivars	Geographical origin	Soil type	pH	Organic matter	K (ppm)	P (ppm)	N (ppm)
Spunta 1	North Greece (Macedonia)	Sandy clay loam	5.43	1.9	321	279	6
Agria 1	North Greece (Macedonia)		5.48	1.85	118	326	5
Spunta 2	Central Greece (Thessaly)	Sandy loam	6.4	5.89	312	56	88
Agria 2	Central Greece (Thessaly)		5.1	7.1	333	36	40
Spunta 3	South Greece (Peloponnese)	Sandy loam	7.6	1.56	296	29	75
Agria 3	South Greece (Peloponnese)		7.2	3.69	289	39	45

Table 2. Effect of cultivar and geographical origin in pH, total acidity, firmness and dry matter of tubers. (Statistical differences for $p \leq 0,05$, L.S.D.: Least Significant Differences (a, b,c))

Source of Variance		pH	Total acidity (%)	Firmness (Nt)	Dry matter (%)
Factors					
Potato cultivars	Spunta	6.08 b	0.14	68.24 b	23.41
	Agria	6.23 a	0.12	78.87 a	23.13
L.S.D.		0.14	-	1.78	-
Regions	Northern Greece	6.28 a	0.13 b	72.99b	24.74 a
	Thessaly	6.15 b	0.10 c	74.35ab	24.04 ab
	South Greece	6.04 c	0.15 a	73.33c	21.03 c
L.S.D.		0.12	0.02	1.35	2.3
Mean		6.15	0.13	73.55	23.27

Table 3. Effect of cultivar and geographical origin in sensory characteristics of fresh potato tubers. Evaluation scale 1-9. (Statistical differences for $p \leq 0.05$. L.S.D.: Least Significant Difference (a, b, c)

Source of Variance		Skin colour	Skin brightness	Internal colour	Surface wrinkling	Odour intensity	Moisture	Surface roughness	Stains
Factors									
Potato cultivars	Spunta	4.21 b	5.08	4.24 b	2.50	3.70	5.21	3.56 b	3.47 b
	Agria	6.44 a	4.90	6.44 a	2.23	3.88	5.65	5.04 a	4.90 a
L.S.D		0.48	-	0.72	-	-	-	0.84	0.95
Regions	Northern Greece	5.53 ab	4.42 c	5.12 bc	2.47 a	3.97	5.78 a	5.36 a	5.95 a
	Thessaly	5.43 b	5.42 a	5.57 ab	2.47 a	3.65	5.22 bc	4.00 b	3.63 b
	South Greece	5.01c	5.12 ab	5.32 b	2.16 b	3.76	5.28 c	3.55 c	2.98 c
L.S.D		0.42	0.7	0.45	0.31	-	0.50	0.45	0.65
Mean		5.32	4.99	5.34	2.37	3.79	5.43	4.30	4.30

Table 4. Effect of cultivar and geographical origin in sensory characteristics of boiled potato tubers. Evaluation scale 1-9. (Statistical differences for $p \leq 0.05$. L.S.D.: Least Significant Difference (a,b,c))

Source of Variance		Odour Intensity	Moistness	Special Taste	Sweet taste	Aftertaste persistence	Metallic taste	Flavour intensity	Mastication	Pastiness	Elasticity	Overall acceptability
Factors												
Potato cultivars	Spunta	4.65b	4.84	4.52b	4.05b	4.74b	2.87	3.18	3.12	2.57	1.60	5.70b
	Agria	5.15a	5.20	6.21a	6.52a	6.32a	3.07	2.81	2.88	2.42	1.41	6.95a
L.S.D		0.38	-	0.68	0.75	0.54	-	-	-	-	-	0.52
Regions	Northern Greece (Macedonia)	4.58bc	4.55c	5.35ab	5.27	5.66ab	3.25a	3.43a	3.43a	2.51	1.71 a	6.72a
	Central Greece (Thessaly)	4.88b	5.11ab	5.05b	5.23	5.18b	2.30b	2.46c	2.66b	2.48	1.21b	6.23bc
	South Greece (Peloponesse)	5.22a	5.40a	5.71a	5.35	5.75a	3.37a	3.10b	2.91b	2.50	1.61ab	6.03c
L.S.D		0.32	0.56	0.66	-	0.47	0.95	0.33	0.52	-	0.40	0.48
Mean		4.90	5.02	5.37	5.28	5.53	2.97	3.00	3.00	2.50	1.51	6.33

Table 5. Effect of cultivar and geographical origin on chemical composition (ppm, mg/Kg of dry weight) of the fresh potato tuber (Statistical differences for $p \leq 0.05$, L.S.D.: Least Significant Differences (a,b,c)

Source of Variance		K	N	P	Cu	Zn	Mn	Fe
Factors								
Potato cultivars	Spunta	181.77 b	94.13 a	80.49 b	4.65 b	5.91 b	31.0 b	32.29 b
	Agria	250.04 a	74.33 b	158. 48 a	10. 84 a	14. 0 a	59.55 a	90.0 a
L.S.D		30.2	5.42	24.5	1.24	0.87	4.82	5.74
Regions	Northern Greece	175.92 c	85.21 b	87.83 c	7.06 b	9.27 b	37.82 b	52.54 b
	Thessaly	221.09 b	78.21 c	125. 50 b	8.13 a	10. 91 a	64.73 a	72.98 a
	South Greece	250.72 a	89.26 a	145.12 a	8.05 a	9.69 ab	33.28 b	57.93 b
L.S.D		29.2	4.56	20	0.98	0.42	4. 5	5.39
Mean		215.91	84.23	119.48	7.749	9.96	45.28	61.15

Table 6. Full names, abbreviations and explanations of parameters used in Principal Component Analysis

Abbreviations	Explanation	Abbreviations	Explanation
Colour	Skin colour	Sp.taste	Special taste
I.colour	Internal colour	Swe.taste	Sweet taste
Bright	Skin brightness	Aft.pers.	Aftertaste persistence
Odour	Odour intensity	Met.taste	Metal taste
Wrinkl.	Surface wrinkling	Pastin.	Pastiness
Moistur.	Moistness	Mastic.	Mastication
Rough	Surface roughness	Flav.int.	Flavour intensity
Stains	Stains	Elastic.	Elasticity
Odour	Odour intensity	O.accept.	Overall acceptability
Moisture	Moistness		

Table 7. Discriminant Function of sensory characteristics for boiled potato tubers

Cultivar / Region	Standardized Canonical Discriminant Function Coefficients	Variance (%)
SPUNTA 1	Overall acceptability = -1.08 Special taste + 0.80 Sweet taste + 0.72 Aftertaste persistence + 0.57 Odour intensity	92%
SPUNTA 2	Overall acceptability = 2.08 Odour intensity + 4.46 Moistness – 0.23 Special taste -1.54 Sweet taste – 0.51 Aftertaste persistence + 3.00 Metal taste -0.92 Pastiness -2.10 Mastication + 4.59 Flavour intensity + 0.10 Elasticity	92%
SPUNTA 3	Overall acceptability = 0.93 Odour intensity + 0.73 Special taste -1.84 Aftertaste persistence + 0.77 Mastication	77%
AGRIA 1	Overall acceptability = 1.62 Moistness + 0.42 Special taste -1.38 Sweet taste	96%
AGRIA 2	Overall acceptability = -0.66 Aftertaste persistence + 0.85 Moistness	89%
AGRIA 3	Overall acceptability = 0.67 Special taste + 0.72 Sweet taste	72%

Regions (1:Macedonia, 2: Thessaly, 3: Peloponesse)

Full names

Principal Component Analysis (PCA), Discriminant Analysis (DA), Cluster Analysis (CA),

Analysis of Variance (ANOVA)

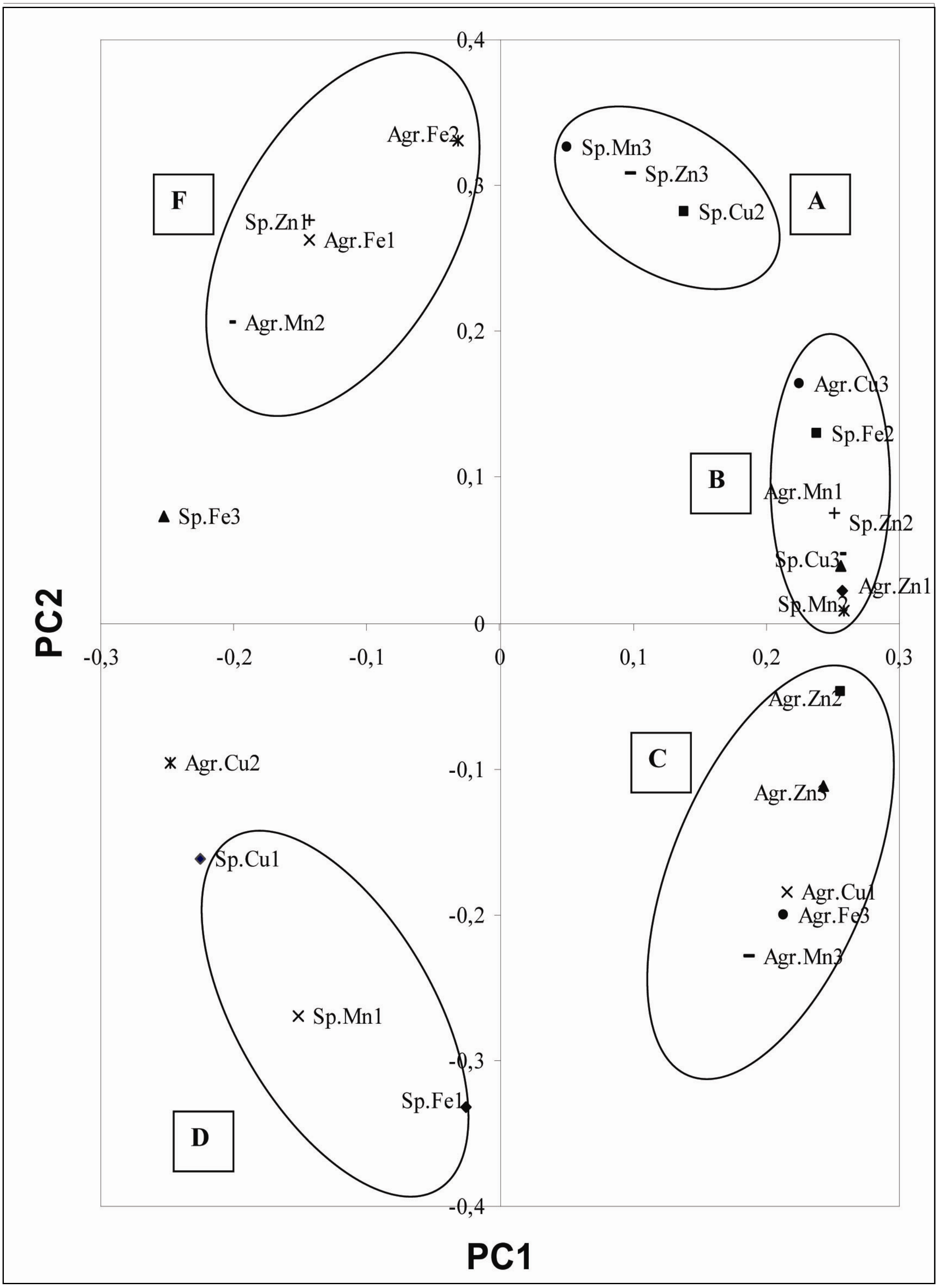

Figure 1. Principal component analysis of metals of potato tubers

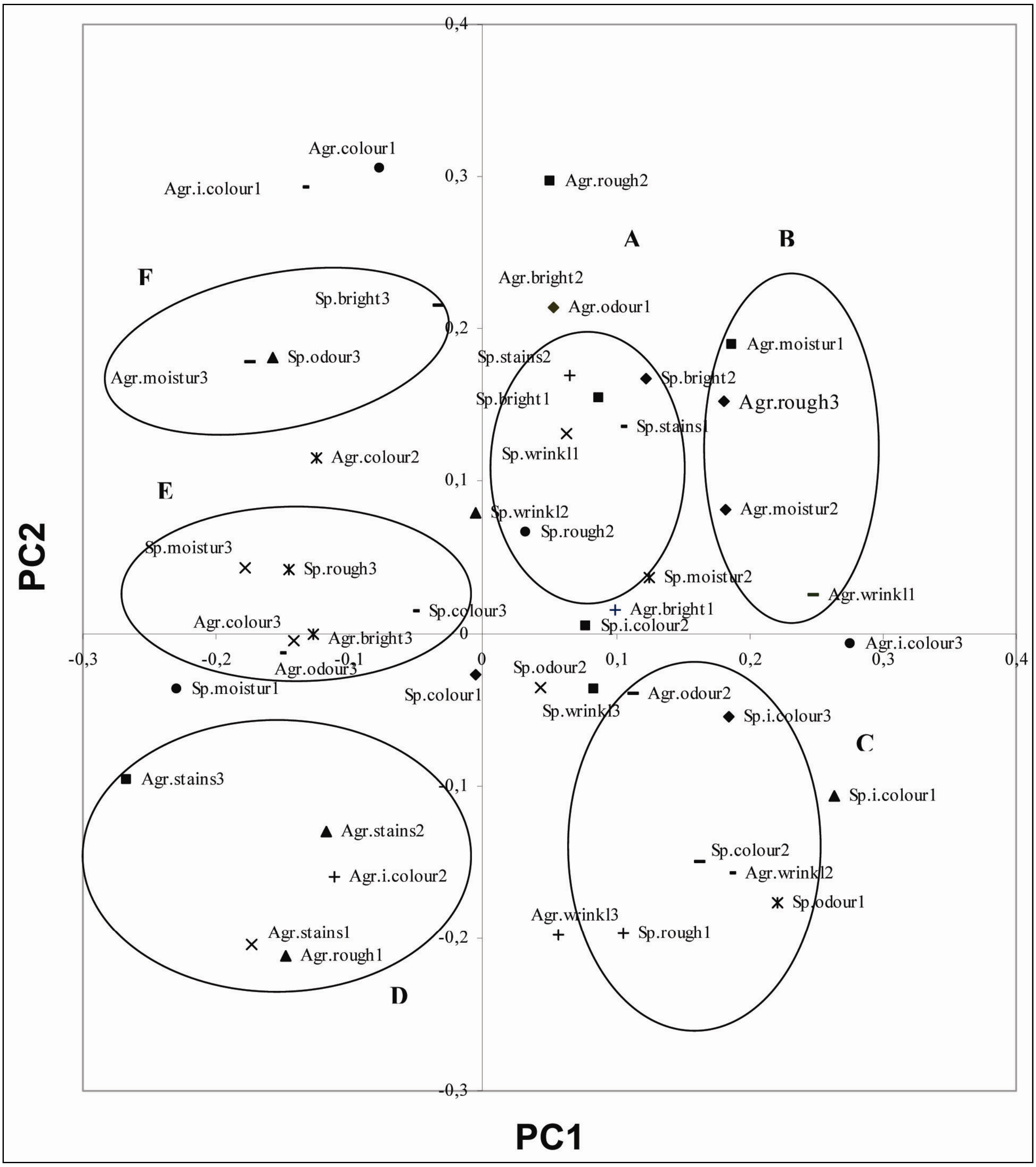

Figure 2. Principal component analysis of sensory characteristics of fresh potato tubers

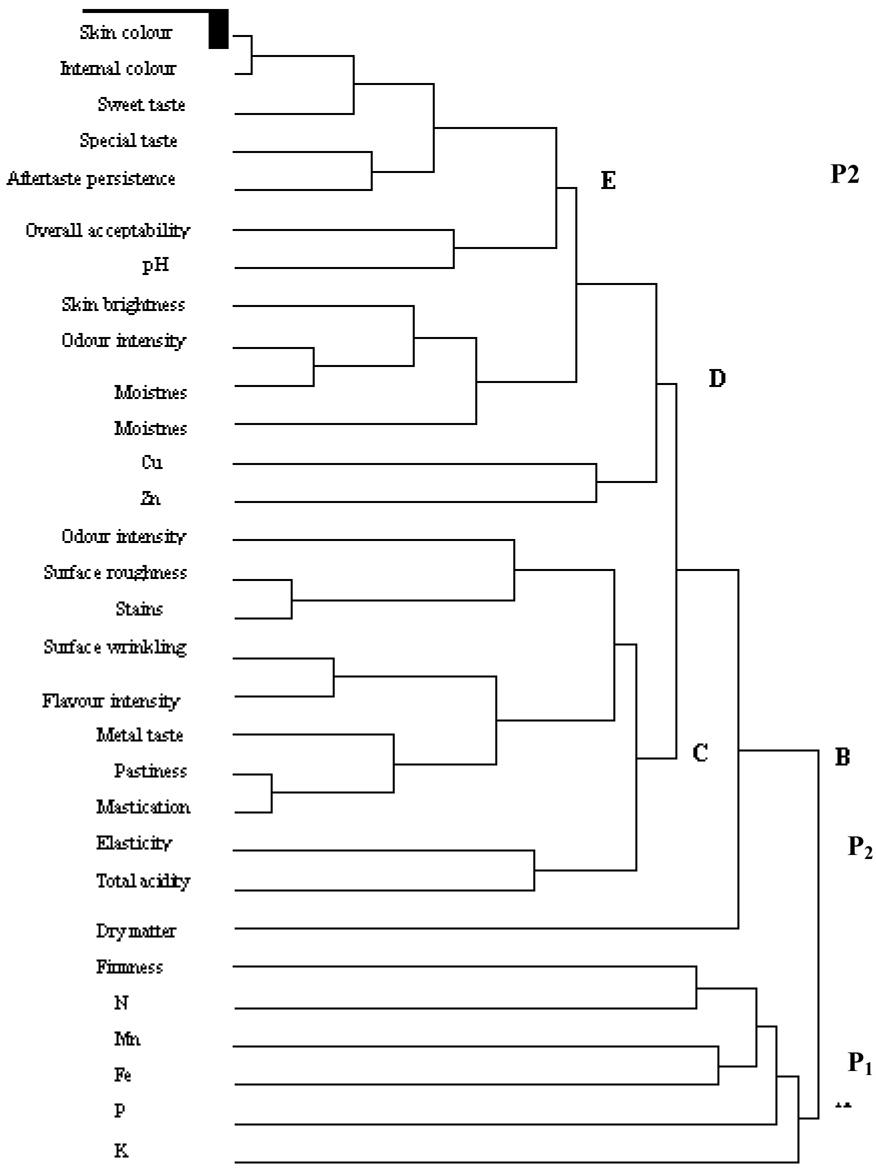

Figure 3. Cluster Analysis of physicochemical and sensory characteristics based on effect of potato cultivar

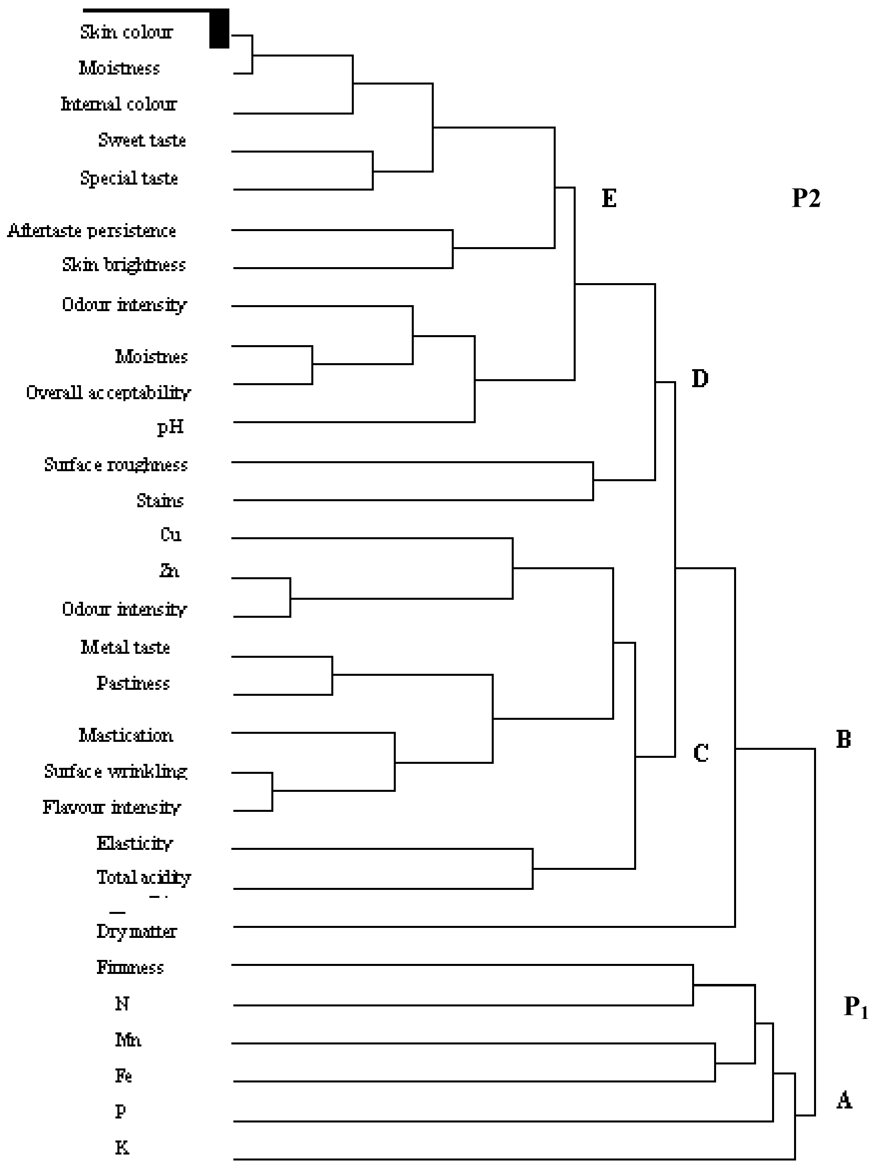

Figure 4. Cluster Analysis of physicochemical and sensory characteristics based on effect of geographical origin