Coffee Quality and Its Interactions with Environmental Factors in Minas Gerais, Brazil

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Abstract

The aim of this work was to assess the geographic distribution of coffee quality in Minas Gerais state, Brazil, and to study its interactions with chemical and environmental factors. Correlations between environmental factors, chemical compounds and sensory quality of participants of the Minas Coffee Quality Contest were made through Principal Component Analysis and Biplot Graphics. The results showed discriminations of high and low scores as a result of environmental variables, demonstrating a strong influence of temperature, rainfall, altitude and latitude on the quality of the coffees studied. In addition to the environmental characteristics, the chemical compounds trigonelline, caffeine, and especially the acid-5-cafeiolquinic were also relevant in discriminating the scores obtained through sensory analysis. This work is an initial indication of the factors that determine the quality of coffees produced in Minas Gerais.

Keywords: Coffee, Quality, Latitude, Altitude, Environment

1. Introduction

Brazilian coffee is mostly produced in the states of São Paulo, Espírito Santo, Bahia, Paraná, Rondônia and Minas Gerais, and coffee from each state has its own characteristics based on the environment and technological aspects of production. Minas Gerais is located in the Southeast region of Brazil, between the parallels 14º 13' 57'' and 22º 55' 47'' latitude South and between the meridians 39º 51' 24'' and 51º 02' 56'' longitude West, completely within the intertropical zone. With a territorial area of 582,586 km^2, Minas Gerais makes up 6.9% of the total area of Brazil and stands out as the country's largest coffee producer with a stake of 50.99% of the coffee produced in Brazil (Companhia Nacional de Abastecimento, 2008; Fundação Centro Tecnológico de Minas Gerais, 1983).

Its large territorial size and environmental variety makes it possible for the state of Minas Gerais to produce quality coffees with a great diversity of flavor and aroma. These differences are related to the particular characteristics of each municipality, mainly the climate variations, altitude and production systems.

Minas Gerais coffee lands are divided into the following four main macro-environments: Sul de Minas (South/Southwest region of the state), Matas de Minas (Zona da Mata and Rio Doce regions), Cerrados de Minas (Triangulo Mineiro and Alto Paranaiba regions) and Chapadas de Minas (Vale do Jequitinhonha and Mucuri regions).

Both domestic and international coffee markets have a growing demand for specialty coffees. Consumers seek exceptional taste and aroma as well as balanced characteristics of sweetness, acidity and body. In addition to the sensory qualities of the coffee, there is also a great interest in products with marketable characteristics of production environment and geographic location (Rodrigues et al., 2009).

Each year the state government, in partnership with the Minas Gerais Rural Technical Assistance Corporation (Empresa de Assistencia Técnica Rural de Minas Gerais – EMATER) and the Federal University of Lavras (Universidade Federal de Lavras – UFLA), holds the Minas Coffee Quality Contest. This initiative seeks to improve the quality and increase the market value of products produced in Minas Gerais by rewarding the competitors that submit the best coffee (based on physical and sensory characteristics).

The flavor and aroma of coffee are affected by the presence of various volatile and nonvolatile chemical constituents, such as proteins, amino acids, fatty acids and phenolic compounds, and also by the action of enzymes on some of these components. In addition to the chemical composition of the coffee, post-harvest processing also influences the final quality and characteristics of the product. Environmental factors, such as altitude and rainfall, have been highlighted as contributing to the quality of the coffee beverage, but further studies are needed to investigate additional environmental characteristics that affect coffee quality (Rodrigues et al., 2009; Avelino et al., 2002; Avelino et al., 2005; Decazy et al., 2003).

The aim of this work was to study the geographic distribution of the coffee in the Minas Coffee Quality Contest in 2007; also of interest was the relationship between the sensory quality and the chemical compounds trigonelline, caffeine and 5-caffeoylquinic acid (5-CQA) and the environmental characteristics of the municipalities of the 60 samples that were finalists in this contest.

2. Materials and Methods

2.1 Description of the Minas Gerais Coffee Regions

The environmental characteristics of the state of Minas Gerais were described in the Ecological and Economic Zoning of the State – ZEE (Scolforo et al., 2008). This publication provided a macro-diagnostic description with the aim of subsidizing the management of different regions of the state according to socio-economic and environmental sustainability criteria. The description provided in the ZEE provides a relevant basis for this paper.

The southern region of Minas is composed of the geographical areas limited by the parallels 21º 13’ to 22º 10’ latitude South and 44º 20’ to 47º 20’ longitude West. This region is characterized by high altitudes, ranging from 700 to 1200 m, and a humid climate (climate classification between types B2 and B3 according to Carvalho et al., 2008), which is predominant in a large part of the region (Minas Gerais, 2008; Fundação Centro Tecnológico de Minas Gerais, 1983). According to the classification system of ABIC, Brazilian Association of Coffee Industry (Associação Brasileira da Indústria de Café, 2009), the types of coffee produced in this region have moderate body and sweetness, with medium to high concentrations of citric acid.

The region Cerrados de Minas is composed of the geographical areas limited by the parallels 16º 37’ to 20º 13’ latitude South and 45º 20’ to 49º 48’ longitude West. This region is characterized by highland areas with altitudes ranging from 820 to 1100 m and a humid climate (type B1 according to Carvalho et al., 2008) in the largest part of the region (Minas Gerais, 2008; Fundação Centro Tecnológico de Minas Gerais, 1983). According to the ABIC classification (Associação Brasileira da Indústria de Café, 2009), the coffee Pulped Natural has excellent aroma and sweetness, is full-bodied and has good presence.

The Matas de Minas region is composed of the geographic areas limited by the parallels 40º 50’ to 43º 36’ latitude South and 18º 35’ to 21º 26’ longitude West and is characterized by mountainous areas, with altitudes ranging from 400 to 700 m. Annual rainfall rages between 1077 and 1647 mm and climatic types vary from humid to dry sub humid (types B1, B2 B4 and C1, C2 according to Carvalho et al., 2008). The coffee produced in this region is characterized by having good body, with moderate acidity and sweetness (Minas Gerais, 2008; Fundação Centro Tecnológico de Minas Gerais, 1983; Associação Brasileira da Indústria de Café, 2009).

The Chapadas de Minas region is composed of the geographic areas limited by the parallels 17º 05’ to 18º 09’ latitude South and 40º 50’ to 42º 40’ longitude West. It is characterized by areas with high ridges, with elevations around 1099 m, and by annual rainfall averages that vary from 700 to 1300 mm. The region is free of frost and the weather is subdivided into the Dry Sub-humid and Semi-arid climatic types (types C1 and D, according to Carvalho et al., 2008). The coffee in this region has consistent aroma and beverage characteristics as well as balanced body and acidity (Minas Gerais, 2008; Fundação Centro Tecnológico de Minas Gerais, 1983; Associação Brasileira da Indústria de Café, 2009)

The coffee regions of Minas Gerais have also been described by Rios (1997) in the form of a map, which has been adapted for this study as shown in Fig. 1.

2.2 The Minas Gerais Contest on Coffee Quality

This work was carried out with data from the IV Minas Coffee Quality Contest (IV Concurso de Qualidade dos Cafés de Minas) held in 2007. Only coffee samples from the species *Coffea arabica* L., type 2 or better (according to the Normative Instruction nº 8 of the Brazilian Agriculture Ministry, Brasil, 2003) were accepted for the contest. The coffee beverage was required to be soft or superior, sieve 16 or above, with a maximum leakage of 5% and a maximum water content of 11.5%. The contest received coffee from everywhere in the state, and the samples were classified geographically according to the original municipality. The coffee samples underwent several stages of evaluation and classification. Samples were separated into two categories: natural coffee and cherry parchment coffee. The physical aspects of the samples were evaluated in the first stage, and the sensory attributes were evaluated from the second stage on. Each evaluation was conducted by a judging panel composed of at least ten classifiers and tasters. The sensory analysis was carried out according to the Brazil Specialty Coffee Association - BSCA (2007) methodology, which evaluates the beverages based on taste, aroma, body, acidity, sweetness and fragrance and gives marks from 0 to 100. The contest data were provided by EMATER in the form of an electronic spreadsheet containing the following information about the samples: the municipality, category and evaluation score. In the 2007 edition, the total number of coffee samples registered in the contest was 1161.

2.3 Description of the Sensory Analysis in the Quality Contest

The samples were roasted to a medium roast, and the color of toasted grains was monitored with the help of a hard Agstron 45. After grinding and straining through a sieve (15 mesh) for uniformity of size, samples were weighed into 10-gram aliquots of coffee and prepared for the tasting table.

Sensory analysis was conducted by four assessors who were accredited by the BSCA. Samples were labeled with codes for analysis by the assessors. Each taster agreed to assess, on average, forty samples in the morning and forty samples in the afternoon, following a mid-day gap in the contest. The tasters used a sequence of samples for tasting and individually recorded scores and observations.

By assigning a range of points, the tasters evaluated the aroma of the coffee in three parts: dry powder, crust and infusion. They then evaluated the coffee based on 9 attributes and assigned a point score, which indicated whether the coffee had sensory characteristics that fell into the class of specialty coffees; the attributes for assessment were clean cup, sweetness, acidity, body, flavor, aftertaste, uniformity, balance and overall score. The coffees selected as finalists obtained scores above 80 points.

2.4 Geographical Distribution and Environmental Characteristics of the Samples in the Contest

The Geographic Information System open source TerraView (Note 1), was used for the environmental characterization and analysis of the spatial distribution of the samples studied. The 1161 samples were evaluated spatially based on the geographic location (latitude and longitude) of the town where they originated. Using the GIS, the data were integrated with the state of Minas Gerais digital geographic base, made available by the GeoMinas (Minas Gerais, 2009). The temperature, rainfall and humidity index data were generated by the ZEE (Carvalho et al., 2008) in Geotiff format.

2.5 Chemical Analysis: Trigonelline, Caffeine and 5-CQA

Among the samples approved in the fourth stage of the contest, 60 finalists' samples were randomly selected for chemical analysis of the following compounds: trigonelline, caffeine and 5-CQA.

The choice of these 60 finalists' coffee samples was based on a sampling plan that included 30 samples from each processing category (natural and cherry parchment). In each group of 30 samples, 15 coffee samples with scores over 80 points and 15 with scores below 75 points were selected. The samples were geo-referenced with a GPS using the geographic coordinates of each of the participants' farms.

The chemical analysis was carried out in the Soil and Plants Nutrition Laboratory of the Institute of Agricultural Research of Minas Gerais (EPAMIG - Empresa de Pesquisa Agropecuária de Minas Gerais), located in Lavras, Minas Gerais. The non-volatile compounds caffeine, trigonelline and 5-CQA were measured by high-performance liquid chromatography (HPLC) according the method of Malta and Chagas (2009). For the extraction, 0.5 g samples of ground raw coffee diluted in boiling distilled water were used. The extract was then filtered with a Qualy® filter paper. A second filtration with a 0.45 µm Millipore membrane was performed before the HPLC readings. The measurement of the chemical compounds was performed with a Schimadzu chromatograph, with a diode array detection system (model SPD-M10A), C18 chromatography column (250 x 4.6 mm, 5 µm), and using a wavelength of 272 nm. The mobile phase consisted of a water: acetic acid ratio of 20:80:1, with 1 mL min-1 flux. For the identification and quantitative analysis, a standard curve was prepared using standards of caffeine, trigonelline and 5-CQA.

2.6 Principal Components Analysis (PCA) of the Chemical, Environmental and Sensory Quality Variables

The data were grouped in an electronic spreadsheet according to their town, category, latitude, longitude, altitude, temperature, rainfall, humidity index, trigonelline, chlorogenic acids, caffeine and sensory analysis scores.

Multivariate techniques, such as principal components analysis, were used (Johnson & Wichern, 2007) and the results were displayed as biplot graphics (Isaaks & Srivastana, 1989).

The purpose of these techniques was to study the chemical and environmental variables that are important in contributing to the scores obtained in competition. The main objective of this multivariate analysis was to reduce the dimensionality of the original set of variables, with the least possible loss of information and to allow the grouping of similar characteristics through graphic dispersions in a bi- or tri-dimensional space (Mingoti, 2005).

2.7 Geostatistic Analysis

The spatial dependence (based on the variables of altitude, latitude and longitude) of the scores obtained in the first stage of the contest was studied with the geostatistics program, R, using the Package GeoR (Note 2).

3. Results and Discussion

3.1 Relationship between Altitude, Latitude and Coffee Quality

The results show that the distance between the spatially correlated samples is approximately 800 km; beyond this, there is no additional spatial correlation between samples.

It should be noted that the adequacy of the exponential model adjustment to the experimental data was considered acceptable because the estimated value $\hat{\gamma}(\mathbf{h})$ repeated the expected trend with regard to the distance, h. Following this model, the adjustment of the area was performed using the kriging method (Houlding, 2000) because estimates based on this model are more precise and, therefore, more reliable.

Fig. 2 shows the surface obtained from the altitude, latitude and sensory quality data. The results prove that the beverage quality scores varied with the altitude, as a function of the latitude. In other words, the higher the altitude, the higher the score and the higher the latitude, the lower the need for high altitude to get a better score. This relationship was also noted by Avelino et al. (2005) who studied the effects of the exposure of the steeper slopes and different altitudes on the quality of the Costa Rica coffee terroirs. Other authors have also noted a relationship between geographical location and the influence of altitude on coffee characteristics in 20 regions of the world (Rodrigues et al., 2009).

3.2 Discrimination between High and Low Scores by Principal Components Analysis

According to the principal components analysis, the determination of high and low scores is related to chemical, environmental and sensory quality variables.

The equations of the main components were estimated according to each factor presented in Tables 1 and 2. The coefficient of greater numbers to the first component was given by the moisture index and of lower numbers was given by the trigonelline concentration, both for natural coffee and for cherry parchment coffee.

The equations of the first two main components, PC1 and PC2, were obtained using the method of Johnson and Wichern (2007), by creating a matrix of correlation of the coffee samples' chemical, environmental and sensory quality variables. Although values presented for the first and second component are not high (46.00 and 18.04%), respectively, these values were sufficient to discriminate between the different processing categories of coffee in relation to environmental factors and quality parameters.

The results for cherry parchment coffees are shown in Table 1. The estimated coefficients for the two first components related to natural coffee are described in Table 2. As seen in Tables 1 and 2, the component PC1 is composed of environmental variables, and PC2 is composed of chemical variables.

The environmental and chemical variables that showed better correlation with the scores are represented in the biplot graphics in Fig. 3. The vectors indicate the variables that were determinant for the given score. To complement this, the scores graphic provided by each main component was able to discriminate the low scores (B) in the 1st and 4th quadrants and the high scores (A) in the 2nd and 3rd quadrants, as seen in Fig. 4.

The low scores (Fig. 4) were mainly influenced by the following variables: humidity index, rainfall and 5-CQA, as indicated by the vectors in the biplot graphic in Fig. 3. While working with the correlation between the quality of coffee beverages and the presence of chemical compounds, Farah et al. (2006) observed that the presence of 5-CQA is associated with beverages of lower quality. According to the literature, a reduction in the quality of coffee correlates with an increase in phenolic substances (Clifford, 1985; Mazzafera & Robson, 2000).

Amorim and Silva (1968) reported that chemical compounds, such as chlorogenic acids, exert a protective action. This action is explained by Cortez (1997), who observed that in humid and hot areas, during maturation and harvest, the moisture in the air promotes the activity of microorganisms that detract from the quality of the drink. Fig. 3 (B) and Fig. 4 (B) show the results for cherry parchment coffee. As seen in the biplot graphic in Fig. 3 (B), the vectors that indicate the variables that best discriminate the high scores from the low scores were the chemical variables trigonelline and caffeine, and the environmental variable temperature. Temperature was the variable that most contributed to the discrimination between scores. According to Malta and Chagas (2009) trigonelline is an important precursor of the volatile compounds that contribute to the aroma and taste of roasted coffee. Working with the *cafés-terroir* in Honduras, Avelino et al. (2002) noted that the effect of temperature is conditioned by the latitude and altitude and that those attributes jointly favor coffee quality, producing the local characteristics of taste and aroma.

The graphics in Fig. 3(B) and Fig. 4(B) show a distribution similar to the graphics seen in Fig. 3(A) and Fig. 4(A) for natural coffee. The variables that contributed most to the discrimination of high scores were temperature, trigonelline and caffeine and the variables that correlated with low scores were rainfall, humidity index and 5-CQA. However, for cherry parchment coffee, as seen in Fig. 4(B), the component long (longitude) provided a small contribution to the discrimination of low scores when evaluating the whole set of nine variables. This contribution was not seen for natural coffee.

4. Conclusions

The chemical variable 5-CQA, and the environmental variables humidity index and temperature, can be used to discriminate the drinking quality of coffee with dry processing, i.e., natural coffee. For peeled coffee, temperature was the variable that most contributed to the discrimination of high scores. The spatial analysis of coffee sample scores shows that the higher the altitude, the higher the score awarded in the contest. In lower latitudes, the influence of altitude on producing the best quality coffee was lower.

Through this study, it was possible to pinpoint the factors that determine and characterize the quality of coffee in the state of Minas Gerais. Similar studies have not yet been carried out for coffee from other regions of Brazil. This work was exploratory and illustrative, in that the geographical coordinates used referred to the municipal centers of origin of the samples and were not accurate enough to formulate clear predictions about the spatial quality. However, due to the environmental variability and territorial scope of Minas Gerais, the results provide a first "snapshot" of the spatial distribution of the quality of coffee produced in the state and its relationship to the geographical environment.

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Notes

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Note 2. Available in: (The R Project for Statistical Computing) www.r-project.org, 2008.

Table 1. Coefficients of the equations of the two first components, estimated by sampling the correlation matrix of the cherry parchment coffee chemical, environmental and quality variables

Variable	PC1	PC2
Latitude	0.386	-0.232
Altitude	0.281	0.171
Longitude	0.230	0.344
Temperature	-0.458	0.035
Rainfall	**0.441**	0.093
Humidity index	**0.469**	-0.013
Trigonelline	-0.086	**-0.537**
5-CQA	0.160	**-0.554**
Caffeine	-0.131	-0.343
Score	0.213	-0.276

Table 2. Coefficients of the equations of the two first main components, estimated by sampling the correlation matrix of the natural coffee chemical, environmental and quality variables

Variable	PC1	PC2
Latitude	0.394	-0.122
Altitude	0.261	0.240
Temperature	-0.465	0.028
Rain fall	**0.408**	-0.071
Humidity index	**0.472**	-0.111
Trigonelline	-0.096	**-0.620**
5-CQA	0.140	**-0.399**
Caffeine	-0.139	**-0.605**
Score	0.350	-0.024

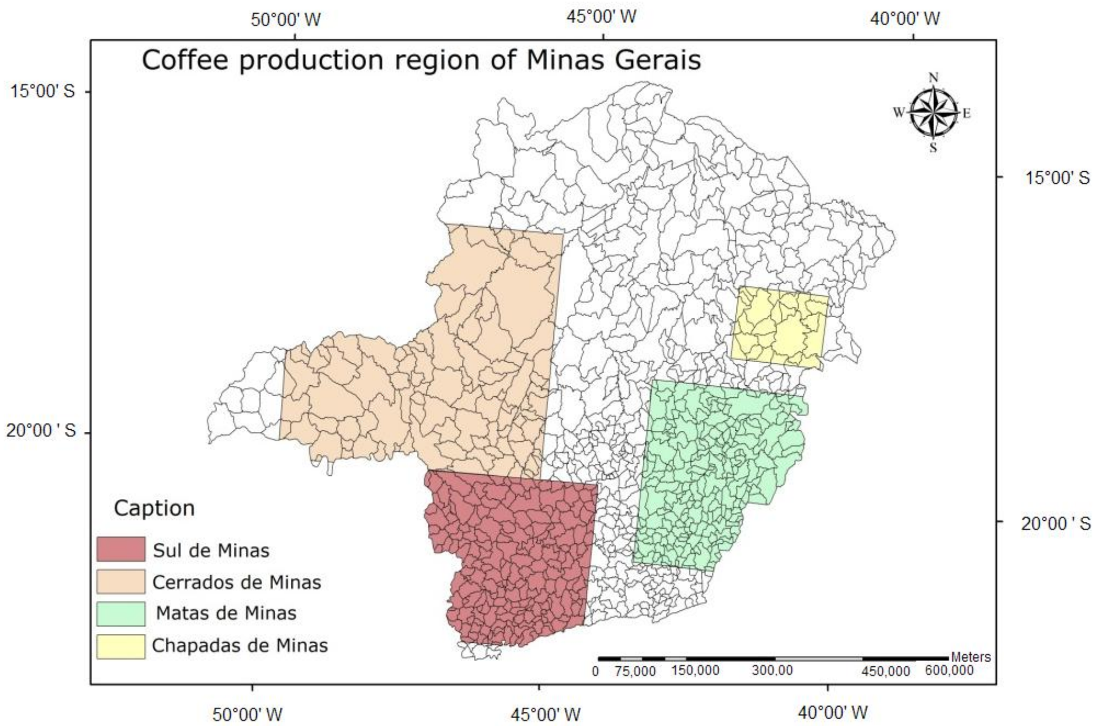


Figure 1. Map of the coffee regions in the State of Minas Gerais, adapted by Rios (1997)

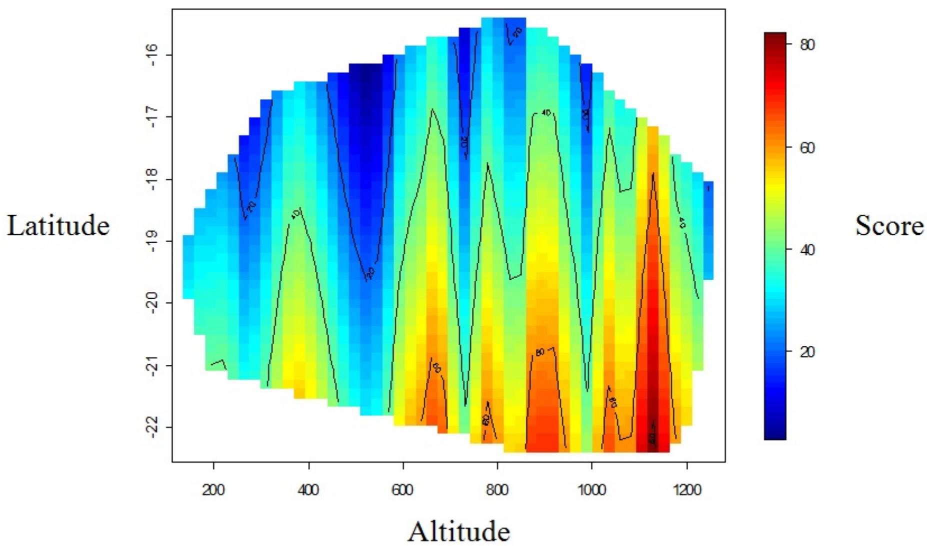


Figure 2. Coffee samples surface, showing the relationship of the beverage quality score, altitude and latitude

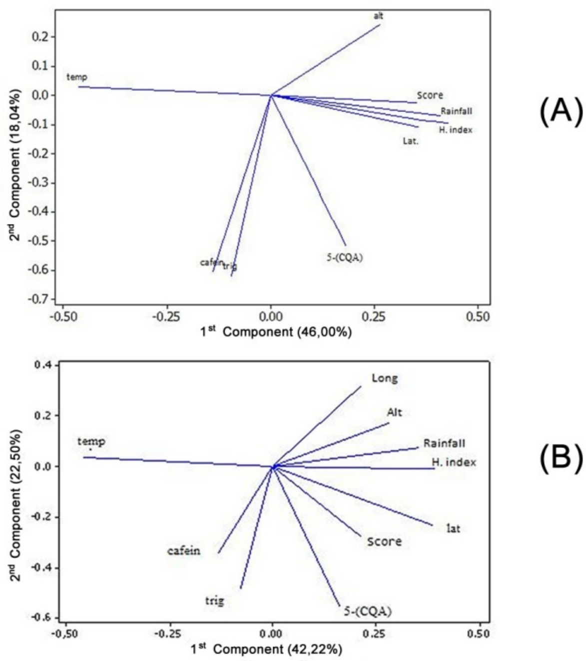
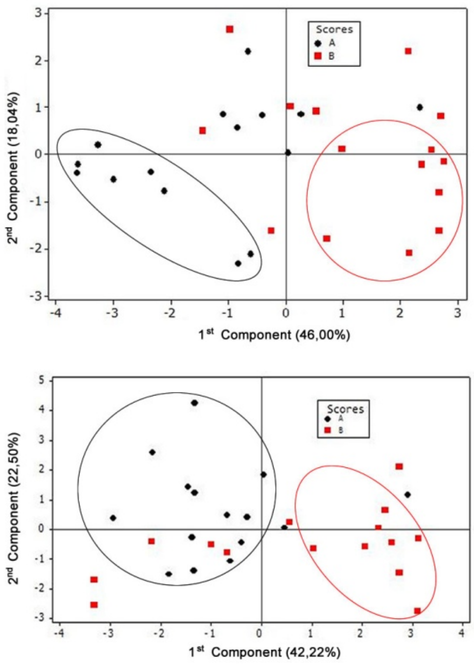


Figure 3. Biplot of the environmental, chemical and sensory quality variables for (A) natural coffee and (B) cherry parchment coffee. Score, rainfall, humidity index (H. index), temperature (temp), altitude (alt), latitude (lat), longitude (long), trigonelline (trig), caffeine (cafein) and 5-CQA



(A)

(B)

Figure 4. Scores of the two first main components for (A) natural coffee and (B) cherry parchment coffee

A = High scores; B = Low scores