

Spatial distribution of coffee from Minas Gerais State and their relation with quality

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SUMMARY

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.

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 14° 13' 57'' and 22° 55' 47'' latitude South and between the meridians 39° 51' 24'' and 51° 02' 56'' longitude West, completely within the intertropical zone. With a territorial area of 582,586 km², 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.

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 Paranaíba 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.

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.

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.

MATERIALS AND METHODS

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 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 (Figure 1).

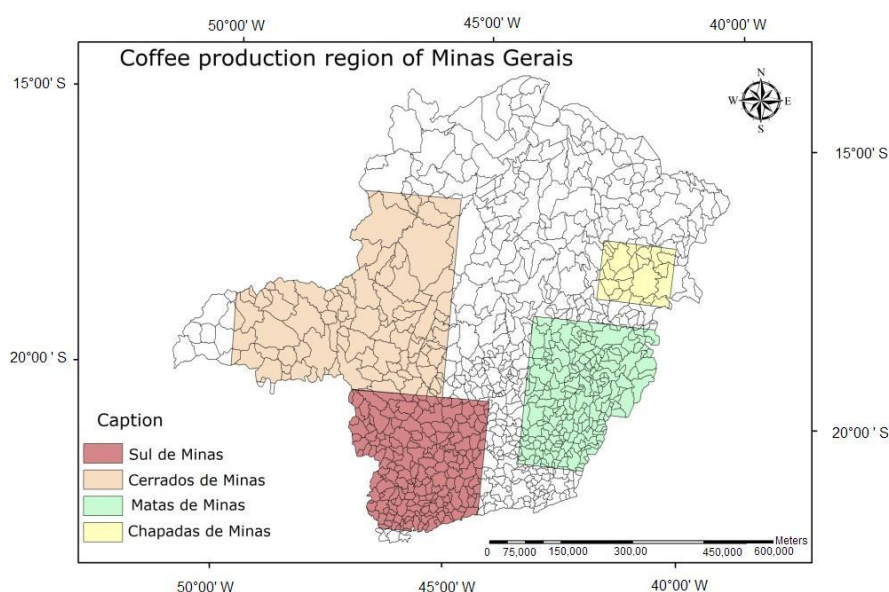


Figure 1. Map of the coffee regions in the State of Minas Gerais, adapted by Informe agropecuário.

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 – 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.

Geographical distribution and environmental characteristics of the samples in the contest

The Geographic Information System open source TerraView, 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. The temperature, rainfall and humidity index data were generated by the ZEE in Geotiff format.

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 non-volatile compounds caffeine, trigonelline and 5-CQA were measured by high-performance liquid chromatography (HPLC) according the method of *Acta Scientiarum Agronomy*. 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 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.

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 and the results were displayed as biplot graphics.

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.

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).

RESULTS AND DISCUSSION

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 $\hat{\gamma}(h)$ repeated the expected trend with regard to the distance, h . Following this model, the adjustment of the area was performed using the kriging method because estimates based on this model are more precise and, therefore, more reliable.

Figure 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.

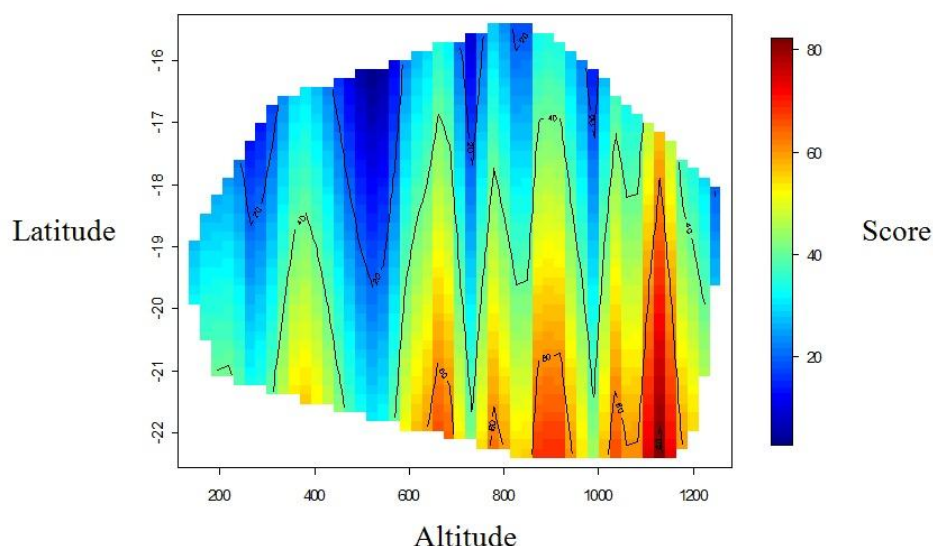


Figure 2. Coffee samples surface, showing the relationship of the beverage quality score, altitude and latitude.

This relationship was also noted by Avelino et al. 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.

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 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 *Applied Multivariate Statistical Analysis*, 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 environmental and chemical variables that showed better correlation with the scores are represented in the biplot graphics in Figure 3.

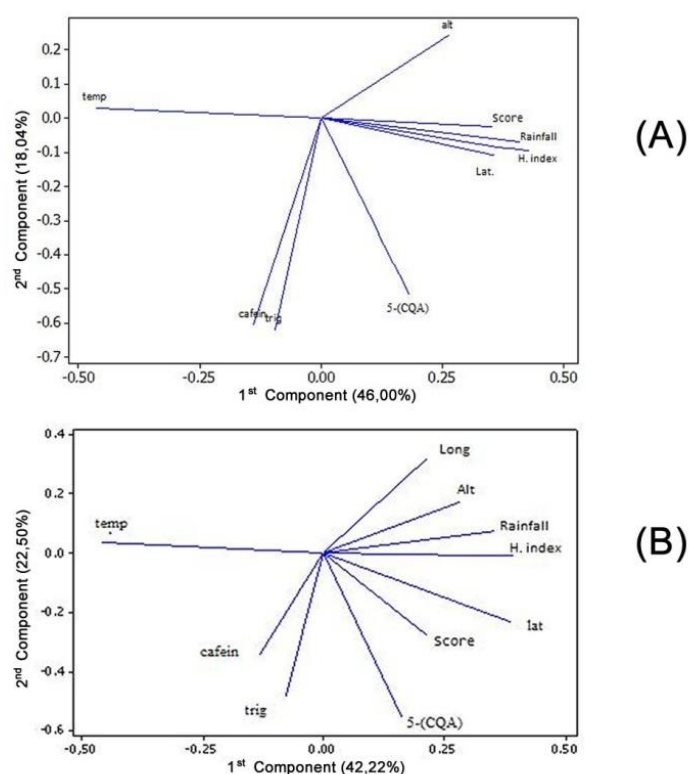


Figure 3. Biplot of the environmental, chemical and sensory quality variables for (A) natural coffee and (B) cherry parchment coffee. Score, rainfall, humidity index (H. index), temperature (temp), altitude (alt), latitude (lat), longitude (long), trigonelline (trig), caffeine (cafein) and 5-CQA.

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 Figure 4.

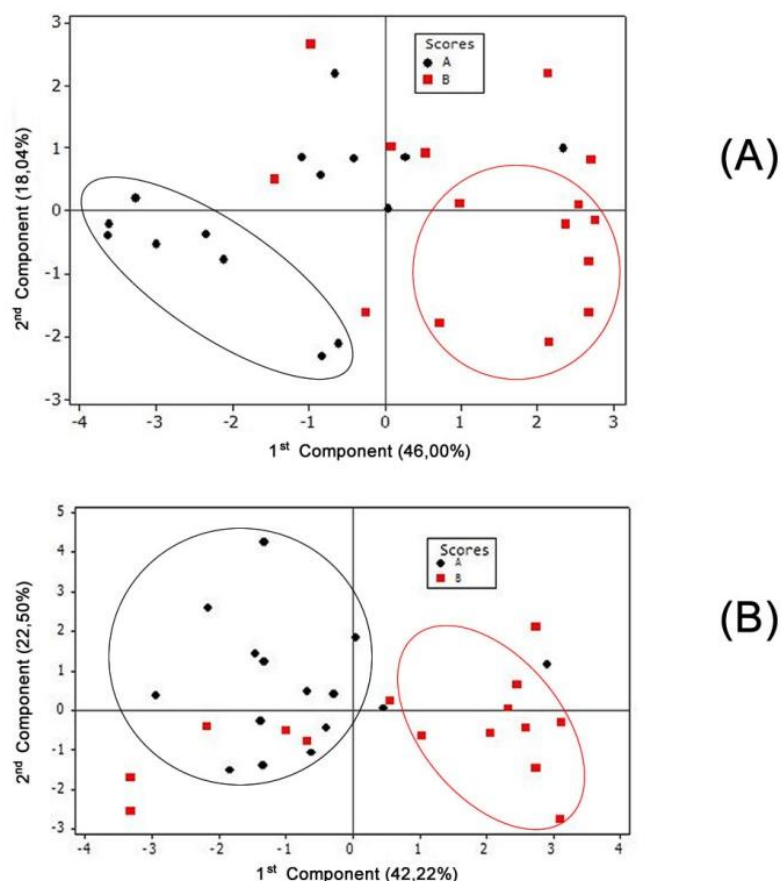


Figure 4. Scores of the two first main components for (A) natural coffee and (B) cherry parchment coffee. A = High scores; B = Low scores.

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. 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.

Nature reported that chemical compounds, such as chlorogenic acids, exert a protective action. This action is explained by Cortez et al., 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 *Acta Scientiarum Agronomy* 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. 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 Figure 3(B) and Figure 4(B) show a distribution similar to the graphics seen in Figure 3(A) and Figure 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 Figure 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.

REFERENCES

- Companhia Nacional De Abastecimento. (2011). Central de informações agropecuárias. Available in: <<http://www.conab.gov.br/>>. Accessed on August 15, 2011.
- Fundação Centro Tecnológico De Minas Gerais. (1983). *Diagnostico ambiental do Estado de Minas Gerais*. Belo Horizonte: CETEC, (Série de Publicações Técnicas, 10). ISSN-0100-9540.
- Rodrigues, C. I., Maia, R., Miranda, M., Ribeirinho, M., Nogueira, J. M. F., Máguas, C. (2009). Stable isotope analysis for green coffee bean: a possible method for geographic origin discrimination. *Journal of Food Composition and Analysis*. 22, 463-471. <http://dx.doi.org/10.1016/j.jfca.2008.06.010>.
- Avelino, J., Perriot, J. J., Guyot, B., Pineda, C., Decazy, F., Cilas, C. (2002). *Ver une identification de cafés-terroir au Honduras*. Montpellier Cedex: Plantations Recherche Developpement. ISBN: 2876146061.
- Decazy, F., Avelino, J., Guyot, B., Perriot, J. J., Pineda, C., Cilas, C. (2003). Quality of Different Honduran Coffees in Relation to Several Environments. *Journal of Food Science*. 68, 2357-2361. <http://dx.doi.org/10.1111/j.1365-2621.2003.tb05772.x>.
- Avelino, J., Barboza, B., Araya, J. C., Fonseca, C., Davrieux, F., Guyot, B., Cilas, C. (2005). Effects of slope exposure, altitude and yield on coffee quality in two altitude terroirs of Costa Rica, Orosi and Santa María de Dota. *Journal of the Science of Food and Agriculture*. 85, 1869-1876. <http://dx.doi.org/10.1002/jsfa.2188>.
- Barbosa, J. N., Borém, F. M., Cirillo, M. A., Malta, M. R., Alvarenga, A. A., Alves, H. M. R. Coffee quality and its interactions with environment factors in Minas Gerais, Brazil. *Journal of agricultural science*. V.4, n.5. p.181-190, 2012.
- Brasil. (2003). Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa n. 08, de 11 de junho de 2003. Available in: <http://www.pr.gov.br/claspar/pdf/cafebenef008_03.pdf>. Accessed on August 15, 2011. <http://dx.doi.org/21000.006212/2002-41>
- Rios, J. N. G. (1997). Certificado de origem e Qualidade do café. *Informe agropecuário*. 18. 69-72. ISBN: 01003364.
- Brazil Speciality Coffee Association - Bsca. (2007). Cafés especiais. Available in: <http://www.bsca.com.br>. Accessed on August 15, 2011. ISSN: 1838-3439.
- Minas G. (2009). Secretaria de Estado da Agricultura. Mapas Geopolítico de Minas Gerais. IGA/CETEC. Available in: <<http://www.geominas.mg.gov.br>>. Accessed on August 15, 2009.
- Carvalho, L. G., Oliveira, M. S., Alves, M. C., Vianello, R. L., Sediya, G. C., Castro Neto, P., Dantas, A. A. A. (2008). *Clima*. In J. R. Scolforo, L. M. T. Carvalho, A. D. Oliveira (Ed.). *Zoneamento Econômico Ecológico de estado de Minas Gerais: Componente geofísico e biótico*. (pp. 89-102). Editora UFPA. ISBN: 9788587692535.

- Malta, M. R., Chagas, S. J. R. (2009). Avaliação de compostos não-voláteis em diferentes cultivares de cafeeiro produzidas na região Sul de Minas Gerais. *Acta Scientiarum Agronomy*. 31, 57-61. <http://dx.doi.org/10.4025/actasciagron.v31i1.6629>.
- Johnson, R. A., Wichern, W. D. (2007). *Applied Multivariate Statistical Analysis*, (385-398). Prentice Hall. ISBN 10: 0131877151.
- Isaaks, E. H., Srivastana, R. M. (1989). *An introduction to applied geostatistics*. Oxford University, 561p. ISBN 0195050134.
- Mingoti, S. A. (2005). *Análise de dados através de métodos de estatística multivariada: uma abordagem aplicada*. Editora UFMG. ISBN 857041451X
- Houlding, S. W. (2000). *Practical Geostatistics: modeling and spatial analysis*. Springer Verlag. 159p. http://dx.doi.org/10.1007/3-540-48019-6_3.
- Farah, A., Monteiro, M. C., Calado, V., Franca, A. S., Trugo, L. C. (2006). Correlation between cup quality and chemical attributes of Brazilian coffee. *Food Chemistry*. London, 98, 373-380. <http://dx.doi.org/10.1016/j.foodchem.2005.07.032>.
- Clifford, M. N. (1985). Chlorogenic acids. In R. J. CLARKE & R. MACRAE (Ed.) *Coffee* (pp. 153-202). *Elsevier Applied Science*. [http://dx.doi.org/10.1016/0308-8146\(87\)90167-1](http://dx.doi.org/10.1016/0308-8146(87)90167-1).
- Mazzafera, P., Robinson, S. P. (2000). Characterization of polyphenol oxidase in coffee. *Phytochemistry*. 55, 285-296. ISSN/ISBN: 00319422.
- Amorim, H. V., Silva, D. M. (1968). Relationship between the polyphenol oxidase activity of coffee beans and the quality of beverage. *Nature*. 219. 381-382. <http://dx.doi.org/10.1590/S0103-90161993000200008>.
- Cortez, J. G. (1997). Aptidão climática para qualidade da bebida nas principais regiões cafeeiras de Minas Gerais. *Informe Agropecuário*. 18, 27-31. <http://dx.doi.org/10.1590/S0100-204X2004000200013>.