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Fatty acid profiles and parameters of quality of specialty coffees produced in different Brazilian regions

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Although fatty acids are known to be important components of coffee flavor and aroma, no study relating such compounds to the quality of coffee has been conducted. Considering the importance of attaining maximum flavor and aroma in specialty coffees, we aimed to investigate the relationship between the fatty acid composition and sensory characteristics of different Bourbon genotypes cultivated under different edaphoclimatic conditions. Four genotypes of arabica coffee were evaluated on the fatty acid profiles and parameters of quality. The genotypes were evaluated in three Brazilian locations. For the first time, we showed that sensory attributes are the most suitable potential discriminators of specialty coffees. In addition, assessing the levels of fatty acids allowed us to obtain information about the key compounds that positively or negatively affect coffee beverage quality. Saturated fatty acids, including arachidic, stearic and palmitic acid are potential discriminators of the quality of specialty coffees, indicating better sensory quality. Conversely, unsaturated fatty acids, including elaidic, oleic, linoleic and linolenic acid may be related to coffees with less intense acidity, fragrance, body and flavor.

Key words: Sensory evaluation, environment, bourbon coffee, chemical compounds, gas chromatography.

INTRODUCTION

The lipid content in coffee grounds ranges from 10 to 17%. However, compared to *Coffea canephora*, higher lipid contents are found in Arabica coffees (Feldman et al.,1969). The majority of lipids are found in the oil fraction of the coffee bean endosperm. The coffee oil fraction is mainly composed of triacylglycerols, which have fatty acid proportions similar to those found in edible vegetable oils (Speer and Kölling-Speer, 2006).

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Triacylglycerols are relatively large molecules that present low volatility and, therefore, they have little contribution to formation of flavor and aroma. However, edible oils and fats from different natural sources have flavor profiles differentiated by the presence of characteristic volatile compounds, such as the byproducts of lipid oxidation and natural impurities (Dhingra et al., 1998). Fatty acids may also contribute subtle and enjoyable flavor notes. Therefore, the aroma and flavor perceived in food are usually influenced by the type and concentration of lipids. Lipids also influence the mouth feel of several foods (Damodaran et al., 2007).

Lipids play an important role in the sensory qualities of several plants, such as soy, cocoa and oats (Gutkoski and El-Dash, 1999). Triacylglycerols are important carriers of aroma in roast coffee beans (Petracco, 2005). The fatty acid (FA) fraction of triacylglycerols releases byproducts of oxidation, which are induced by temperature and mainly comprise aldehydes that react with intermediates of the Maillard reaction, providing additional flavor and aroma to the coffee (Flament, 2001). Studies relating flavor and aroma to fatty acid composition are more frequent in products of animal origin (Wood et al., 2008). Conversely, among the few scientific reports describing the influence of fatty acids on the sensory quality of products of vegetal origin, some reports are notable (Gutkoski and El-Dash, 1999; Stephan and Steinhart, 2000). Considering the relevance of sensory quality to the production of specialty coffees (Borém et al., 2013), the evaluation of the contribution of fatty acids to the flavor and aroma of coffees is justified.

The production of specialty coffees has become one of the main strategies for maintaining the economic viability of coffee production, especially in regions where high costs of production make the production of regular coffees impractical. Thus, the production of specialty coffees has been stimulated due to their higher value and demand. Brazil has an enormous diversity of coffee genotypes, which are cultivated in different regions of the country. Such genetic and environmental variability can supply demands on the production of coffee, including aspects related to quality. Coffee quality is described by its physical and sensory characteristics and is related to other aspects, such as chemical traits, crop systems, processing, etc. However, all of these aspects depend on the genotype and environmental conditions where the coffee is cultivated (Pereira et al., 2010; Pezzopane et al., 2012).

Among the available cultivars for plantations, the Bourbon cultivar is of special interest due to its high potential to produce coffee of excellent beverage quality because of its differentiated sensory characteristics. This cultivar is frequently used to produce specialty coffees in several regions of the world (Figueiredo et al., 2013).

The environmental conditions in which coffee trees are grown directly influence the chemical composition of their fruits and consequently the quality of the final product (Avelino et al., 2005; Joët et al., 2010a; Taveira et al., 2014). The influence of the climatic conditions during seed development on the final composition of fatty acids has been described in several oilseeds, particularly in terms of temperature and precipitation (Byfield and Upchurch, 2007; Fofana et al., 2006). The content of fatty acids can discriminate the origin of several plants, such as pistachio (Arena et al., 2007), hazelnut (Amaral et al., 2006) and olive (Ollivier et al., 2006). Some studies have reported the discrimination of coffees in different geographic regions based on their content of fatty acids (Bertrand et al., 2008; Joët et al., 2010b; Rui Alves et al., 2003).

However, although fatty acids are known to be important components of the flavor and aroma of coffee (Flament, 2001; Jham et al., 2008a; Petracco, 2005), to date, no study relating such compounds to the quality of coffee has been conducted. In other words, the term quality reflects the sensory characteristics of coffee, which includes fragrance, flavor, acidity, body, aftertaste, and balance. Considering the importance of attaining maximum flavor and aroma in specialty coffees and the influence of genetic and environmental factors on the final beverage quality, we investigated the relationship between the fatty acid composition and sensory characteristics of different Bourbon genotypes cultivated under different edaphoclimatic conditions.

MATERIALS AND METHODS

Chemical compounds

Palmitic acid (PubChem CID:985); Stearic acid (PubChem CID:5281); Elaidic acid (PubChem CID:637517); Oleic acid (PubChem CID:445639); Linoleic acid (PubChem CID:5280450); Arachidic acid (PubChem CID:10467); Linolenic acid (PubChem CID:5280934).

Experimental conditions

Four genotypes of *Coffea arabica* L. grown in three locations were evaluated (Table 1). The studied genotypes were grown in experimental field plots since 2005 in the southern region of the state of Minas Gerais and in the region of Mogiana in the state of São Paulo, including in the municipalities of Lavras, MG; Santo Antônio do Amparo, MG and São Sebastião da Grama, SP. The data in the present work represent the harvests of three agricultural crop seasons (2008/2009, 2009/2010, and 2010/2011).

The biome Mata Atlântica predominates in the Mogiana region, which is located in the interior of the state of São Paulo, with the presence of rupestrian fields. The southern region of the state of Minas Gerais is characterized by a transition between the biomes Cerrado and Mata Atlântica, also with the presence of rupestrian fields. Both regions are highlighted for their production of Arabica coffee on a large scale. The distinct edaphoclimatic conditions of these important Brazilian coffee producing regions were represented in this study, and their main characteristics are shown

Table 1. Studied genotypes and environments and their codes[a].

Environments	Genotypes
A1 = Lavras	G1 = Mundo Novo IAC 502/9
A2 = São Sebastião da Grama	G2 = Yellow Bourbon IAC J9
A3 = Santo Antônio do Amparo	G3 = Yellow Bourbon /Origin SSP[b]
	G4 = Yellow Bourbon /Origin CM[b]

[a]A1, A2, A3, G1, G2, G3 e G4 = codification of the genotypes and environments used in the discussion of the results.[b]SSP = São Sebastião do Paraíso, MG; CM = Carmo de Minas, MG.

Table 2. Geographic region, climatic variables and characterization of the three studied environments.

Municipality	Lavras	São Sebastião da Grama	Santo Antônio do Amparo
Region	**Southern Minas Gerais**	**MogianaPaulista**	**Southern Minas Gerais**
Altitude	919 m	1300 m	1050 m
Mean temperature	20.4°C	20°C	19.9°C
Mean annual precipitation	1460 mm	1560 mm	1700 mm
Latitude	21°14'43"S	21°44'50"S	20°56'47"S
Longitude	44°59'59"W	46°55'33"W	44°55'08"W
Soil type	Clayey Oxisol	Clayey Oxisol	Clayey Oxisol

in Table 2.

Coffee harvest and processing

The coffee fruits were manually and selectively harvested when the fruits were completely mature. Afterwards, the fruits were separated based on differences in their density in a water tank adapted with a sieve, thus guaranteeing the complete uniformity of the material from the different parcels. The higher density fruits were separated from the floating portion of lower density. Although the selective harvest of mature fruits was performed, a small portion of immature fruits was still found in the cherry portion. After the floaters were removed from the sample, another manual selection of the ripe fruits was carried out, resulting in approximately 20 L of coffee fruit, thus guaranteeing the retention of only mature fruits. Then, the coffee fruits were peeled to obtain the pulped coffee.

Drying was carried out immediately after processing. Coffee samples were dried in 1 m² sieves (wooden frame and grille mesh size 2.00 x 1.00 mm, manufactured in polyethylene yarn) in a paved yard. Seven liters of pulped coffee was uniformly distributed per sieve and stirred 20 times a day. The coffee samples were kept spread out and uncovered on the first night, and on the following nights they were covered with black canvas. The thickness of the layer was maintained at 7 L.m² until the coffee attained a constant dryness with a water content of approximately 25% wet basis (w.b.). Then, the thickness of the coffee layer was doubled. This procedure was repeated until the coffee attained a water content of 11% (w.b.). All procedures for harvesting and processing were performed according to Borém (2008).

Sample preparation

After drying, the samples were packed in paper bags and covered with plastics bags, identified, and stored in chambers at a controlled temperature of 18°C for 60 days. Then, the samples were benefited and the defects were removed in order to standardize the samples and minimize interferences unrelated to the genetic material or the environment. Chemical analysis and roasting were performed in beans retained on sieves 16 and higher (16, 17 and 18/64 inches). For the chemical analyses, raw beans were milled for one minute in an 11A basic mill (IKA, Brazil) by adding liquid nitrogen to facilitate the milling and avoid sample oxidation. After milling, the samples were kept in a freezer at -80°C until analysis.

Roasting and sensory evaluation

All procedures were performed according to the protocol described by the Specialty Coffee Association of America - SCAA (Lingle, 2011). In total, 100 g of each coffee sample was roasted in the Probat TP2 (Curitiba, Brazil) for no longer than 24 h before tasting. The roasting was terminated when the coffee samples attained the desired roasting, which was visually determined using a system of color classification employing standardized discs (SCAA/Agtron Roast Color Classification System; reference color number 65 for milled beans and 55 for whole beans). The temperature and time of roasting were monitored by a thermometer and cronometer, respectively, with the time range of roasting between 8 and 12 min.

Samples were weighed to obtain a pre-determined ratio of 8.25 ±0.25 g per 150 ml of water and then milled in a Mahlkönig Guatemala (Hamburg, Germany). Ten sensory attributes were evaluated by a panel of trained judges and scored on a scale of 10 points according to SCAA (Lingle, 2011).The sensory attributes included the aroma, uniformity, absence of injuries, sweetness, flavor, acidity, body, balance, completion and overall impression. The final sensory grade was generated from the sum of all of the evaluated attributes. For each evaluation, five cups of coffee representing each genotype were evaluated, with one session of sensory analysis for each repetition and a total of three repetitions. Each environment was evaluated separately, and the results of the sensory analyses were scored on a scale representing the quality level in intervals of 0.25 points.

In addition to the final grade obtained from the sensory evaluation, the attributes of aroma, acidity, body and flavor were also analyzed statistically in order to complement the analysis, considering that these are the main attributes responsible for distinguishing the different sensory profiles of the coffee.

Extraction of lipids

The samples containing green coffee beans (~ 0.25 g) were weighed in 1.5 ml microcentrifuge tubes, and 1.0 ml of hexane was added to each one. The tubes were then placed in an ultrasonic bath for 10 min to extract the lipids. Afterwards, the lipids were centrifuged at 6,000 rpm for 2 min. Aliquots of 0.5 µl of each supernatant in a 2.0 ml cryogenic tube were evaporated, hydrolyzed, methylated and analyzed by gas chromatography.

Hydrolysis of lipids In total, 10 mg of the oil was dissolved in a 2.0ml cryogenic tube in 100 µl of an ethanol (95%)/potassium hydroxide 1 mol/L (5%) solution. After vortexing for 10 s, the oil was hydrolyzed (Silva and Ferraz, 2006). After cooling, 400 µl of 20% hydrochloric acid, a spatula tip of NaCl, and 600 µl of ethyl acetate were added. After vortexing for 10 seconds and resting for 5 minutes, an aliquot of 300 µl of the organic layer was removed, placed in a microcentrifuge tube and dried by evaporation to obtain the free fatty acids (Christie, 1989).

Methylation of fatty acids

The free fatty acids were methylated with 100 µl BF3/methanol (14%) and heated for 10 min in a water bath at 80°C, then diluted with 300 µl of methanol and analyzed by gas chromatography.

Gas chromatography

Analyses were performed in a gas chromatograph HP5890 equipped with a flame ionization detector. An SP-2380 column (Supelco; 30 m x 0.25 mm) was used with a temperature gradient of 150°C for 1 min, 7 °C/min to 220°C; with an injector (split 1/50) at 250°C and a detector at 250°C; with hydrogen as the carrier gas (2 ml/min); and with an injection volume of 2 µl. Peak identification was made by comparing standards of methylated fatty acids analyzed on a Supelco37 column. The results regarding the content of fatty acids refer to the harvests from 2010 and 2011. The final content of fatty acids is given as the percentage of dry matter (% d.m.). The following fatty acids were quantified by the normalization area method (Christie, 1989): palmitic (C16: 0), stearic (C18: 0), elaidic (C18: 1T), oleic (C18: 1c), linoleic (C18: 2), arachidic (C20: 0) and linolenic (C18: 3).

Statistical analyses

Four genotypes of arabica coffee were evaluated in three production environments. The three experiments were installed following a randomized block design with three repetitions in the field and plots comprising ten plants. The data for the sensory attributes and the content of fatty acids were initially submitted to analysis of variance (ANOVA), and when significant differences by the F test were detected, the Scott-Knott test was applied at a 5% significance level using the software SISVAR®(Ferreira, 2011).

To better understand the effects of the studied variables, the data were also submitted to multivariate analysis. Discrimination among samples was performed using principal component analysis (PCA) based on interactions between the genotype and the environment; groupings were made according to the sensory attributes and chemical compositions using the software Chemoface (Nunes et al., 2012).

RESULTS AND DISCUSSION

Chemical and sensory composition

Figure 1 presents a typical chromatogram of the analyzed samples of coffee. The peaks from the fatty acids and their respective retention times can be observed. The retention time varied from approximately 4.5 to 8 min. A similar chromatogram was obtained by Martín et al. (2001). Table 3 shows the contents of fatty acids (% m. s.), the grades of the analyzed sensory attributes and the final grade of the sensory analysis for each studied genotype and environment as well as the interaction between these factors.

Linoleic (C18:2) and palmitic (C16:0) acids predominated. Moderate amounts of stearic (C18:0), oleic (C18:1c) and arachidic (C20:0) acids and values lower than 1.6% of linoleic (C18:3) and elaidic (C18:1t) acid were also found (Table 3). The compositions of fatty acids obtained from raw grounds of coffee in the present study are in accordance with the values reported in Bertrand et al.(2008); Jham et al.(2008a); Joët et al.(2010a) and Martín et al. (2001). Most of the analyzed fatty acids did not differ among the studied genotypes ($p>0.05$), except for linoleic acid (C18:2) and arachidic (C20:0) acid (Table 3). Jham et al. (2008) also did not find any significant differences among the content of fatty acids in coffee.

Martín et al. (2001) determined the content of fatty acids in coffee by capillary gas chromatography. The fatty acid contents allowed the differentiation of arabica coffee from canephorus. The fatty acids that primarily contributed to the differentiation of the species were oleic, linolenic, linoleic and myristic acids (Martín et al., 2001). The acid profiles differed statistically among the different environments, except for elaidic (C18:1t) and arachidic (C20:0) acid. Environment 3 (A3) had the most different fatty acid profile (Table 3).

Studies of the influence of climatic conditions on the fatty acid compositions of seeds sensitive to cold, such as coffee, are rare (Joët et al., 2010a). In the present work, there were significant differences in the contents of linoleic and oleic acids among the studied environments. Among all of the studied fatty acids, linoleic acid was the only potential marker for differentiating the coffee samples from the three environments. For some fatty acids, the interaction between genotype and environment was significant, thus allowing the distinction of some genotypes in the studied environments (Table 3). There was also a significant interaction between genotype and environment for all of the sensory attributes (fragrance, flavor, acidity and body) and for the final sensory grade, thus emphasizing the effect of the interaction between genotype and environment on the final quality of the coffee.

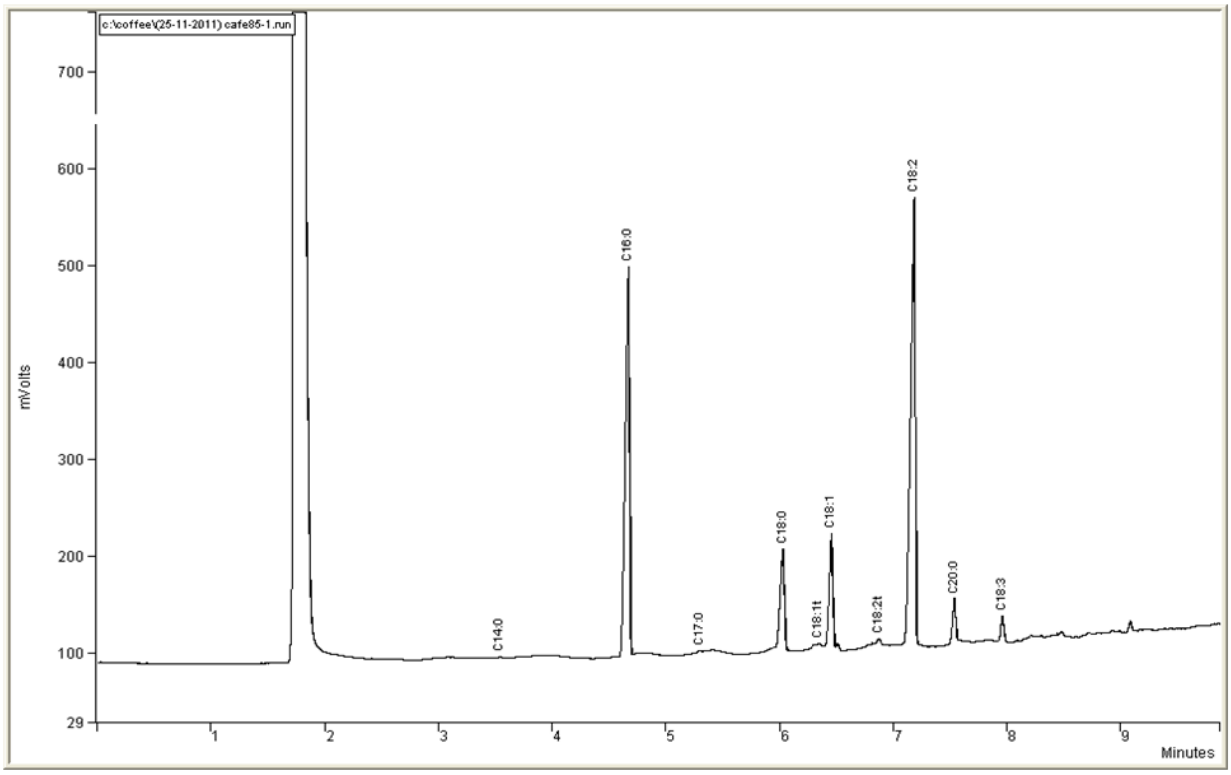

Figure 1. Typical chromatogram of the fatty acids quantified in the analyzed coffees, including palmitic (C16: 0), stearic (C18: 0), elaidic (C18: 1T), oleic (C18: 1c), linoleic (C18: 2), arachidic (C20: 0) and linolenic (C18: 3) acids.

Several factors may influence quality, such as sensory attributes, chemical composition, crop systems, etc. However, all of these factors are encompassed by the general considerations of genetics and plant breeding, which depend on the genetic constitution or genotype, the environmental conditions to which the genotype is subjected, and the interaction between them (Pereira et al., 2010).Because of the complexity of the sensory aspects involved in the characterization of specialty coffees and their relationship to the analyzed fatty acids, the ability of multivariate analysis to interpret the results is limited. Therefore, the data were analyzed by means of PCA, as shown in Figure 2.

Principal component analysis (PCA)

Principal component analysis was applied to interpret the results of the chemical and sensory analyses of the samples of four genotypes (G) of coffee cultivated in three environments (A). A biplot was generated (Figure 2) as a function of the content of fatty acids, the final sensory grade and the sensory attributes.

The first two components explained 73.21% of the variability among the genotypes, among which 46.52% corresponded to the first component and 26.69% corresponded to the second (Figure 2).The data at each point (interaction between genotype χ environment, A_xG_y) are presented as the means of scores, which were calculated based on the three repetitions. Points with similarities in one or more aspects (content of fatty acids and/or sensory attributes) are next on the graph. The representative vectors of each studied variable directed to the points (A_xG_y) detected by the principal components indicate which aspects were determinants for the groupings. The equations of principal components were estimated according to each correlation coefficient presented in Table 4. Such results show, for the first time, a correlation between the sensory characteristics and the composition of fatty acids in the genotypes of Bourbon coffee, which has important implications for the production of specialty coffees.

Three distinct groups were formed when observing the first axis, PC1 (Figure 2): the first, with points on the left part of the biplot (A1G1, A1G4, A3G1, A2G4 and A3G4); the second (II), with points on the central part of the biplot (A3G3 and A3G2); and the third (III), with points on the right part of the biplot (A2G3, A1G3, A2G1, A1G2 and A2G2). The sensory attributes contributed the most in discriminating the groups as a function of the first principal component (Table 4). The coffees in group 1 had a less intense body, fragrance and flavor and lower final sensory grades, contrary to the coffees in group III (Figure 2). Bourbon genotypes were grown in the same

Table 3. Effect of genotype, environment and the interaction between them on the sensory attributes, the final sensory grade, and the content of fatty acids[a] of coffee beans. The means and probability of significance (*F*) were determined by analysis of variance (ANOVA) for the three environments and four genotypes.

Genotype/ environment[b]		C16:0	C18:0	C18:1t	C18:1	C18:2	C20:0	C18:3	Fragrance	Flavor	Acidity	Body	Final
G1		34.47	8.93	1.29	8.94	39.70[a]	3.03[a]	1.51	7.25[a]	7.11[a]	7.25[a]	7.37[b]	80.38[a]
G2		34.53	9.29	1.03	8.66	39.25[b]	3.10[a]	1.60	7.60[b]	7.39[b]	7.38[b]	7.37[b]	81.61[b]
G3		35.02	9.40	1.11	8.67	38.61[b]	3.13[a]	1.55	7.58[b]	7.44[b]	7.43[b]	7.33[b]	81.76[b]
G4		34.03	9.13	1.30	8.54	40.28[a]	2.82[b]	1.54	7.26[a]	7.07[a]	7.15[a]	7.17[a]	79.87[a]
F		0.09	0.05	0.18	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.01	0.00
A1		35.56[a]	9.29[a]	1.15	8.63[a]	38.37[a]	3.09	1.51[a]	7.36	7.20	7.22	7.24	80.59
A2		35.02[a]	9.37[a]	1.16	8.47[a]	39.33[b]	2.98	1.49[a]	7.52	7.35	7.37	7.36	81.42
A3		32.95[b]	8.91[b]	1.25	9.02[b]	40.68[c]	2.99	1.65[b]	7.38	7.22	7.32	7.33	80.70
F		0.00	0.00	0.70	0.00	0.00	0.20	0.00	0.11	0.20	0.07	0.12	0.12
A1	xG1	35.08[a]	9.00	1.35	8.85	38.58[a]	3.22[a]	1.48	7.09[a]	6.95[a]	7.12[a]	7.25[b]	79.64[a]
	xG2	35.68[a]	9.29	0.87	8.67	38.40[a]	3.12[a]	1.60	7.53[b]	7.25[b]	7.27[b]	7.31[b]	80.93[b]
	xG3	36.73[b]	9.64	1.19	8.42	36.68[b]	3.23[a]	1.47	7.58[b]	7.51[b]	7.46[b]	7.36[b]	81.96[b]
	xG4	34.75[a]	9.27	1.17	8.56	39.83[a]	2.79[b]	1.50	7.22[a]	7.07[a]	7.02[a]	7.05[a]	79.86[a]
F		0.02	0.23	0.29	0.39	0.00	0.00	0.11	0.01	0.01	0.00	0.05	0.03
A2	xG1	34.95	9.10	1.12	8.66	39.81	2.90[a]	1.46	7.62[b]	7.40[b]	7.54[b]	7.40	81.89[b]
	xG2	34.94	9.75	1.10	8.50	38.68	3.13[b]	1.48	7.62[b]	7.45[b]	7.35[b]	7.37	81.76[b]
	xG3	34.98	9.42	0.95	8.60	39.31	3.08[b]	1.55	7.68[b]	7.51[b]	7.45[b]	7.37	82.28[b]
	xG4	35.24	9.22	1.48	8.12	39.50	2.79[a]	1.47	7.19[a]	7.03[a]	7.15[a]	7.30	79.77[a]
F		0.96	0.16	0.21	0.16	0.56	0.04	0.33	0.01	0.04	0.03	0.87	0.02
A3	xG1	33.40	8.71	1.40	9.33	40.72	2.96	1.61	7.04[a]	6.99[a]	7.10	7.47[a]	79.63[a]
	xG2	32.97	8.86	1.12	8.80	40.67	3.06	1.73	7.64[b]	7.48[b]	7.52	7.42[a]	82.15[b]
	xG3	33.35	8.93	1.21	9.00	39.85	3.07	1.62	7.48[b]	7.29[b]	7.36	7.26[b]	81.06[b]
	xG4	32.12	9.16	1.26	8.94	41.50	2.86	1.64	7.36[b]	7.12[a]	7.28	7.15[b]	79.98[a]
F		0.19	0.52	0.73	0.22	0.26	0.42	0.14	0.00	0.04	0.06	0.02	0.02

[a]fatty acids in percentage of dry matter (% d.m.): palmitic (C16: 0), stearic (C18: 0), elaidic (C18: 1T), oleic (C18: 1c), linoleic (C18: 2), arachidic (C20: 0) and linolenic (C18: 3). [b]G1 = Mundo Novo IAC 502/9, G2 – Yellow Bourbon IAC J9, G3 = Yellow Bourbon/Origin CM, G4 = Yellow Bourbon/Origin CM, A1= Lavras, A2= São Sebastião da Grama, A3= Santo Antônio do Amparo. Test at the 5% significance level.

municipalities in which our study was performed, and São Sebastião da Grama showed a high potential to produce high quality coffees (Figueiredo et al., 2013). The possibility of differentiating coffee beans of different genotypes grown in different environments according to their chemical profiles was also highlighted by Taveira et al. (2014).

The fatty acids that presented the strongest correlation with the first component were arachidic (C20:0), elaidic (C18:1t), stearic (C18:0) and palmitic (C16:0) acid (Table 4). The coffee beans with better sensory qualities (group III) were positively correlated with arachidic, stearic and palmitic acids and negatively correlated with elaidic acid. The inverse behavior was observed for the coffees in group I (Figure 2, Table 4).The fatty acid composition depends on several factors,

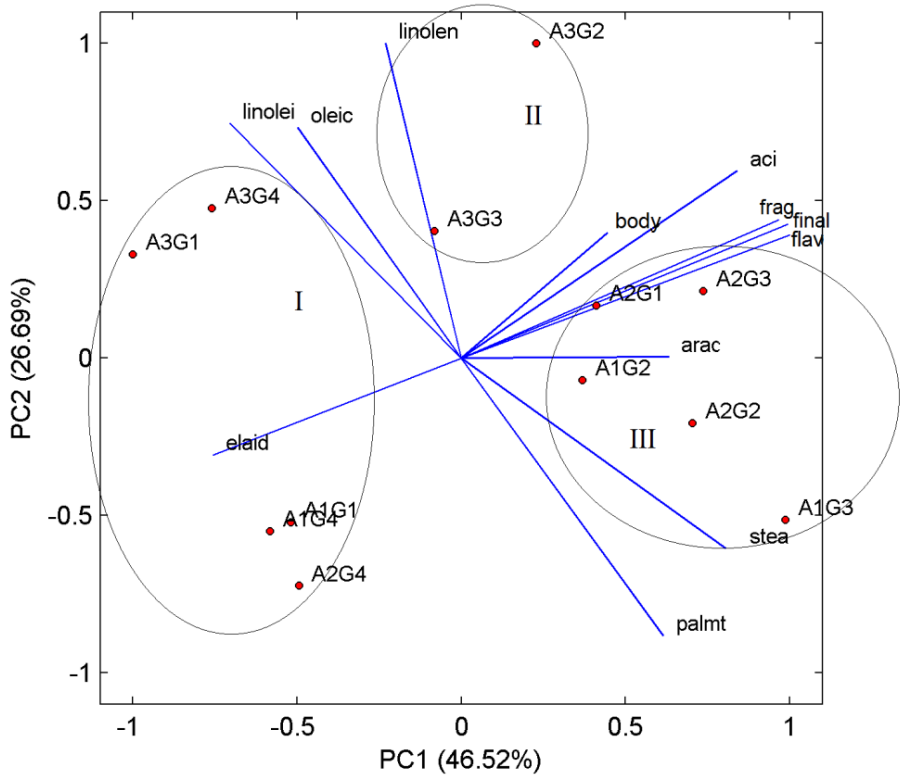

Figure 2. Biplotof the first axes of the principal component analysis for the data from the four genotypes (G) and three environments (A) as a function of the content of fatty acids, the final sensory grade and the sensory attributes. Fatty acids: palmt (C16: 0), stea (C18: 0), elaid (C18: 1T), oleic (C18: 1c), linolei (C18: 2), arac (C20: 0) and linolen (C18: 3). Frag = fragrance, flav = flavor, aci = acidity. G1 = Mundo Novo IAC 502/9, G2 = Yellow Bourbon IAC J9, G3 = Yellow Bourbon/Origin SSP, G4 = Yellow Bourbon/Origin CM, A1= Lavras, A2= São Sebastião da Grama, A3= Santo Antônio do Amparo.

mainly the species and variety (Amaral et al., 2006). Therefore, comparing standards of fatty acids is a useful tool for differentiating coffees (Dagne and Jonsson, 1997). In the present study, arachidic (C20:0), elaidic (C18:1t), stearic (C18:0) and palmitic (C16:0) acids were correlated with the sensory characteristics of coffees, suggesting that they may be possible discriminators of coffee quality.

Stearic acid is a common component in several foods, such as red meats and dairy products. It has many desirable flavor and texture characteristics that are common among long chain saturated fatty acids (Monsma and Ney, 1993). It was previously reported that lack of flavor and flavor imbalance in foods are associated with low levels of saturated fatty acids, such as butanoic and hexanoic acid (Banks et al., 2007).

All of the fatty acids that presented a negative correlation with the first principal component and consequently with the sensory quality were unsaturated fatty acids (elaidic, oleic, linoleic and linolenic acids) (Table 4). The propensity of unsaturated fatty acids to oxidize has been reported; this oxidation leads to the development of rancidity and in many cases to the formation of undesirable aromas, both in vegetal (Jham et al., 2008b) and animal oils (Wood et al., 2008). Our results suggest the association of unsaturated fatty acids with less intense acidity, fragrance, flavor and body, which are highly valued in specialty coffees.

Elaidic acid was the most distinct among the unsaturated fatty acids. Its levels were inversely related to the final sensory grade (Figure 2). All coffees in group I presented higher contents of elaidic acid, less intense sensory attributes, and lower final sensory grades. Elaidic acid is a trans isomer of oleic acid. The trans isomers of unsaturated fatty acids are formed in the frying process as well as during the refining of oils and hydrogenation processes by thermally induced mechanisms (Sebedio et al., 1996). Such compounds are widely studied in relation to technological and nutritional aspects (Stender et al., 2008), but there have been no studies relating elaidic acid to the sensory characteristics of foods. Although it is present in low concentrations in coffees (Table 3), in the present study, the content of elaidic acid was strongly

Table 4. Correlations between the evaluated parameters (fatty acids, final sensory grade and sensory attributes) and the first two principal components.

Parameter	PC1 (46.52%)	PC2 (26.69%)
Fragrance	0.97	0.44
Flavor	1.00	0.39
Acidity	0.84	0.59
Body	0.44	0.40
Final	0.99	0.42
Palmitic	0.62	-0.88
Stearic	0.80	-0.60
Elaidic	-0.76	-0.31
Oleic	-0.50	0.73
Linoleic	-0.61	0.75
Arachidic	0.63	0.00
Linolenic	-0.23	1.00

correlated with the sensory aspects of the evaluated coffees.

The attribute of body was positively correlated with the first principal component (PC1) as well as with the levels of stearic, arachidic and palmitic acids (Figure 2, Table 4). The oil of coffee is mainly composed of triacylglycerols with fatty acids in proportions similar to those found in edible vegetal oils (Speer and Kölling-Speer, 2006). The oils present on the coffee have the capacity to cover the tongue during ingestion, thus providing the oily and creamy mouth feel that is characteristic of the beverage (Illy and Viani, 2005). This study verified the contributions of stearic and arachidic acid to the sensory attribute of body in coffee and to the increase in flavor. The oil of coffee also contains aromatic compounds present in the beverage that may increase or decrease the beverage quality depending on composition (Avelino et al., 2005). Because they are positively correlated with coffee fragrance, stearic and arachidic acid may also be associated with aromatic compounds beneficial to quality. In contrast, elaidic acid may be related to aromatic compounds that are detrimental to the quality of coffee.

Linoleic, oleic and linolenic acid presented more significant contributions to the second principal component (PC2) (Table 4). This second component allowed the differentiation of the points (genotype χ environment) as a function of that fatty acids. Linoleic, oleic, linolenic and palmitic acid allowed the differentiation of environment 3 (A3) from the others. Independent of the evaluated genotype, the coffees cultivated in this environment were positively correlated with the contents of linoleic (C18:2), oleic (C18:1c) and linolenic acid (C18:3) and negatively correlated with the content of palmitic acid (C16:0).

Evaluating the effect of different genotypes and environments and their interaction on the composition of fatty acids in extracts of green coffee beans, Bertrand et al. (2008) observed a high potential of most of the studied fatty acids (palmitic, margaric, stearic, linoleic, linolenic, arachidic and eicosenoic) to differentiate the environments in which the coffees were grown. This ability of fatty acids to discriminate crop origin has also been demonstrated in other fruits and beans, for example, in pistachio (Arena et al., 2007), hazelnut (Amaral et al., 2006) and olive (Ollivier et al., 2006). The influence of climatic conditions during the development of seeds and on the final composition of fatty acids has been reported in many oilseeds (Byfield and Upchurch, 2007; Fofana et al., 2006) and model species of plant. Therefore, it was possible to verify the potential of linoleic, oleic and linolenic acids to both discriminate environment 3 and characterize this environment in relation to the evaluated sensory attributes by determining the negative correlation of these fatty acids with the attributes of acidity, fragrance, body and flavor.For the first time, we showed that sensory attributes are the most suitable potential discriminators of specialty coffees. In addition, assessing the levels of fatty acids allowed us to obtain information about the key compounds that positively or negatively affect coffee beverage quality. Saturated fatty acids, including arachidic, stearic and palmitic acid are potential discriminators of the quality of specialty coffees, indicating better sensory quality. Conversely, unsaturated fatty acids, including elaidic, oleic, linoleic and linolenic acid may be related to coffees with less intense acidity, fragrance, body and flavor.

Inferior sensory quality can also be related to fatty acids, such as elaidic acid, which was present in higher levels in the coffee samples of worse quality. Fatty acids can also potentially differentiate coffee growing environments. In this study, we demonstrate that oleic, linoleic and linolenic acids strongly contribute to the discrimination of the environment in Santo Antônio do Amparo.

Conflict of Interest

The authors have not declared any conflict of interest.

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