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The relationship between organic acids, sucrose and the quality of specialty coffees

Flávio M. Borém[1], Luisa P. Figueiredo[2]*, Fabiana C. Ribeiro[3], José H. S. Taveira[4], Gerson S. Giomo[5] and Terezinha J. G. Salva[5]

[1]Departamento de Engenharia, Universidade Federal de Lavras, Brasil.
[2]Departamento de Ciência dos Alimentos, Universidade Federal de Lavras, Brasil.
[3]Departamento de Agronomia e Medicina Veterinária, Universidade de Brasília, Brasil.
[4]Departamento de Engenharia Agrícola, Universidade Estadual de Goiás, Brasil.
[5]Insituto Agronômico de Campinas, Brasil.

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There is an increasing demand for specialty coffees in the worldwide coffee market, which justifies the need for research focused on understanding the effect of genetic factors and environmental conditions on coffee quality. The aim of this study was to assess the occurrence of arabica coffee genotypes with a high potential for specialty coffee production under three different environmental conditions. Green coffee beans of arabica genotypes largely cultivated in Brazil were chemically evaluated: one Mundo Novo line and three Bourbon lines. The experimental sites were established in fields in three different municipalities (Lavras, Santo Antônio do Amparo and São Sebastião da Grama) located in Brazil. The level of sucrose and oxalic acid was a good discriminant marker for the beverage quality of the genotypes assessed, in which coffees with higher scores also showed higher levels of sucrose and lower levels of oxalic acid. Yellow Bourbon IACJ9 and the Yellow Bourbon/Origin SSP were indicated as the most suitable genotypes for specialty coffee production.

Key words: Specialty coffees, sugar, acids, sensory profile, principal component analysis.

INTRODUCTION

The worldwide demand for specialty coffees has been increasing in larger proportions than for regular coffees. The quality of specialty coffees is related to their intrinsic characteristics, which are represented by the chemical composition of coffee beans. The chemical compounds found in coffee beans provide flavor, aroma, acidity, sweetness and sourness to the beverage (Figueiredo et al., 2015; Giomo and Borém, 2011).

Coffee breeding programs have developed cultivars with the objective of increasing yield and resistance to pests and diseases and have developed short-stature plants that are adapted to several environmental conditions (Petek et al., 2006; Sera, 2001). However, beverage quality is rarely considered as part of this development.

The Bourbon coffee cultivar has received more attention from the coffee market than existing arabica coffee

*Corresponding author. E-mail: luisa.figueiredo@dca.ufla.br.

Table 1. Studied genotypes, 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 and G4 = codification of the genotypes and environments used in the discussion of the results. bSSP = 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	Mogiana Paulista	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

cultivars. That is because it has a high potential to produce differentiated coffees regarding tastes and aromas. However, differences in the production of high-quality beans have been reported among Bourbon genotype lines (Ferreira et al., 2012; Figueiredo et al., 2013, 2015; Taveira et al., 2014).

Coffee expresses its quality differently depending on the place where it is grown. It is essentially a *terroir* product that is directly affected by environmental aspects including nature and human actions (Alves et al., 2011). The production of arabica coffees in Brazil is large, and it is located in places with several different environmental conditions. This diversity of the environments associated with the wide genetic variability allows Brazil to produce coffees with very distinct sensory profiles.

The acceptance of coffee by consumers is related to its quality, which in turn is related to the chemical composition of the coffee beans. Among several classes of chemical compounds, organic acids and sucrose are known to contribute to coffee flavor. Nevertheless, the levels of organic acid and sucrose in coffee beans have already been quantified (Alcázar et al., 2003; Campa et al., 2004; Jham et al., 2002; Ky et al., 2001; Rogers et al., 1999), and there are no reports relating these chemical compounds to the sensory quality of Bourbon genotypes.

The increasing demand for specialty coffees justifies the need for producing countries to invest in research focused on understanding the impact of genetic and environmental factors on final coffee quality. Therefore, the objective of this study was to identify the occurrence of coffee genotypes that have an increased potential for producing specialty coffees in three different Brazilian municipalities as well as to understand the influence of the interaction of genetic and environmental factors on the levels of organic acids and sucrose. In addition, the authors focused on determining the relationship between these chemical compounds and the sensory characteristics of the Bourbon genotypes.

MATERIALS AND METHODS

Experimental conditions

Four genotypes of *Coffea arabica* L. (Table 1) 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 the municipalities of Lavras, MG; Santo Antônio do Amparo, MG and São Sebastião da Grama, SP. 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 in Table 2.

Coffee harvest and processing

Coffee fruits were handpicked and selectively harvested when the fruits were completely mature to guarantee the complete uniformity of the material from the different parcels. Although, the selective harvest of mature fruits was performed, a small portion of immature fruits was still found in the cherry portion. Those unripe fruits were manually removed from the samples, 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

according to the method of Borém et al. (2008), until coffee beans were at the level of 11% (w.b) moisture content.

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). 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.

Chemical analysis

In total, 0.5 g of ground green coffee beans were deposited into a 100 mL flask, mixed with 70 ml of deionized water (18.2 MQ) at 70°C, agitated and then placed into a water bath set at 70°C for 30 min. The flask content was filled to 100 mL with deionized water (18.2 MQ) and then filtered in paper (Schleicher and Schuell filter paper 597.5). Three milliliters of the resulting extract was filtered again in a C18 cartridge (SEP PAK) that had been previously balanced with methanol and 3 mL of water (Rogers et al., 1999). The filtrate was used for further quantitative determination of sucrose and organic acids.

Quantitative determination of sucrose

The concentration of sucrose was measured in two replicates (Pezzopane et al., 2012) using a high performance liquid chromatography (HPLC) Bio-inert quaternary system (Shimadzu Kyoto, Japan), model FCV-10AL-VP, with a pump (Shimadzu, Kyoto, Japan), model LC-10Ai (Kyoto, Japan); automatic injector (Shimadzu, Kyoto, Japan), model SIL-10Ai; electrochemical detector (Dionex, CA, USA), model ED 50; and suppressor (Dionex, CA, USA), model ASRS 300, 4 mm. The column used was a PA1, 250 x 4 mm (Dionex®). Elution was performed in the isocratic mode with a flow rate of 1 $mL.min^{-1}$ at 30°C using 50 $mMol.L^{-1}$ NaOH as an eluent.

Concentrations were calculated from the peak area of the standard solution (Sigma, cat. no. 7903, Sigma. St. Louis, MO). The sucrose levels of the samples collected in 2010 and 2011 were quantified in percentage of dry matter (% d.m.).

Quantitative determination of organic acids

The concentration of organic acids was measured in two replicates using a high performance liquid chromatography (HPLC) Bio-inert quaternary system (Shimadzu, Kyoto, Japan), model FCV-10AL-VP, with a pump (Shimadzu, Kyoto, Japan), model LC-10Ai (Kyoto, Japan); automatic injector (Shimadzu, Kyoto, Japan), model SIL-10Ai; electrochemical detector (Dionex, CA, USA), model ED 50; and suppressor (Dionex, CA, USA), model ASRS 300, 4 mm (Rogers et al., 1999).

Standard solutions of lactic acid, acetic acid, malic acid, oxalic acid and citric acid were used for peak identification in the chromatograms and for the calculation of the sample concentration. The organic acid levels of the samples collected in 2010 and 2011 were quantified in percentage of dry matter (% d.m.).

Statistical analysis

Four genotypes grown in three different environments were assessed. The experiment in each environment was performed in a randomized block design with three replicates comprising 10 plants each.

The sensory profile, final sensory score and organic acid and sucrose content were subjected to ANOVA. The Scott-Knott test was applied with $P<0.05$ using the software SISVAR® (Ferreira et al., 2011) for the significant differences found by the F test.

The dataset comprising the sensory and chemical results underwent a multivariate analysis (Principal Component Analysis-PCA) to get a deeper understanding of the factors using the statistical Chemoface software (Nunes et al., 2012).

RESULTS AND DISCUSSION

Chemical composition and sensory profile

The organic acid levels, sucrose levels, sensory attributes and final score of the sensory analysis are shown in Table 3. Citric acid was found at higher concentrations in the green coffee extracts (~1.32% d.m.). Malic acid was found at an intermediate level in the samples (~0.5% d.m.). Lactic acid, acetic acid and oxalic acid were found to be lower than 0.09% d.m. The sucrose concentration had an average value of 9.72% d.m. The levels of the compounds analyzed are in accordance with reports found in the literature on organic acids (Alcázar et al., 2003; Jham et al., 2002; Rogers et al., 1999) and sucrose (Campa et al., 2004; Ky et al., 2001; Redgwell and Fischer, 2006).

The most abundant organic acids in green coffee beans are citric and malic acids (Ginz et al., 2000). Sucrose represents almost the total of amount of free sugars in green coffee beans. However, its content varies among species. *C. arabica* L. has sucrose levels ranging from 5.1 to 9.4% d.m., whereas *Coffea canephora* has much lower levels, ranging between 4 and 7% d.m. (Campa et al., 2004; Ky et al., 2001).

Table 3. Average concentration of the organic acids, sucrose, final sensory score and sensory attributes (fragrance, taste, acidity and body) of four genotypes grown in three environments. Average and significance of the F test was determined by ANOVA.

Genotype/Environment		Lactic acid	Acetic acid	Malic acid	Oxalic acid	Citric acid	sucrose	Fragrance	Taste	Acidity	Body	Final score
G1		0.08	0.08[a]	0.55[a]	0.05	1.36	9.5[a]	7.25[a]	7.11[a]	7.25[a]	7.37[b]	80.38[a]
G2		0.08	0.08[a]	0.51[a]	0.05	1.36	10.17[b]	7.60[b]	7.39[b]	7.38[b]	7.37[b]	81.61[b]
G3		0.08	0.06[b]	0.46[b]	0.04	1.29	9.88c	7.58[b]	7.44[b]	7.43[b]	7.33[b]	81.76[b]
G4		0.09	0.06[b]	0.53[a]	0.05	1.42	9.34[a]	7.26[a]	7.07[a]	7.15[a]	7.17[a]	79.87[a]
F		0.17	0.04	0.00	0.16	0.31	0.00	0.00	0.00	0.00	0.01	0.00
A1		0.08	0.08	0.49	0.04[a]	1.32	9.03[a]	7.36	7.20	7.22	7.24	80.59
A2		0.09	0.07	0.53	0.04[a]	1.32	10.25[b]	7.52	7.35	7.37	7.36	81.42
A3		0.08	0.06	0.52	0.06[b]	1.43	9.88c	7.38	7.22	7.32	7.33	80.70
F		0.11	0.07	0.06	0.00	0.08	0.00	0.11	0.20	0.07	0.12	0.12
A1	xG1	0.06[a]	0.07[a]	0.50	0.05[b]	1.26	8.86[a]	7.09[a]	6.95[a]	7.12[a]	7.25[b]	79.64[a]
	xG2	0.06[a]	0.10[b]	0.49	0.04[a]	1.37	9.4[b]	7.53[b]	7.25[b]	7.27[b]	7.31[b]	80.93[b]
	xG3	0.09[a]	0.06[a]	0.45	0.04[a]	1.25	9.31[b]	7.58[b]	7.51[b]	7.46[b]	7.36[b]	81.96[b]
	xG4	0.12[b]	0.07[a]	0.51	0.05[b]	1.39	8.56[a]	7.22[a]	7.07[a]	7.02[a]	7.05[a]	79.86[a]
F		0.00	0.01	0.22	0.04	0.50	0.00	0.01	0.01	0.00	0.05	0.03
A2	xG1	0.09	0.08	0.56	0.04	1.34	9.98[a]	7.62[b]	7.40[b]	7.54[b]	7.40	81.89[b]
	xG2	0.09	0.07	0.53	0.05	1.34	10.6[b]	7.62[b]	7.45[b]	7.35[b]	7.37	81.76[b]
	xG3	0.09	0.06	0.50	0.04	1.31	10.49[b]	7.68[b]	7.51[b]	7.45[b]	7.37	82.28[b]
	xG4	0.09	0.06	0.53	0.04	1.31	9.95[a]	7.19[a]	7.03[a]	7.15[a]	7.30	79.77[a]
F		0.81	0.47	0.31	0.46	0.97	0.01	0.01	0.04	0.03	0.87	0.02
A3	xG1	0.09	0.08	0.57[a]	0.06	1.48	9.68[a]	7.04[a]	6.99[a]	7.10	7.47[a]	79.63[a]
	xG2	0.08	0.05	0.50[b]	0.05	1.36	10.51[b]	7.64[b]	7.48[b]	7.52	7.42[a]	82.15[b]
	xG3	0.08	0.05	0.44[b]	0.05	1.32	9.86[b]	7.48[b]	7.29[b]	7.36	7.26[b]	81.06[b]
	xG4	0.07	0.06	0.55[a]	0.06	1.57	9.50[a]	7.36[b]	7.12[a]	7.28	7.15[b]	79.98[a]
F		0.57	0.19	0.00	0.18	0.13	0.00	0.00	0.04	0.06	0.02	0.02

G1= Mundo Novo IAC 502/9, G2= Bourbon Amarelo IAC J9, G3= Bourbon Amarelo/Origem SSP, G4= Bourbon Amarelo/Origem CM, A1= Lavras, A2= São Sebastião da Grama, A3= Santo Antônio do Amparo.

Among the chemical compounds analyzed, sucrose was the only one that was different ($P<0.05$) in green coffee bean extracts according to different genotypes, environments and interactions between genotype and the environment. Most of the genotypes did not differ

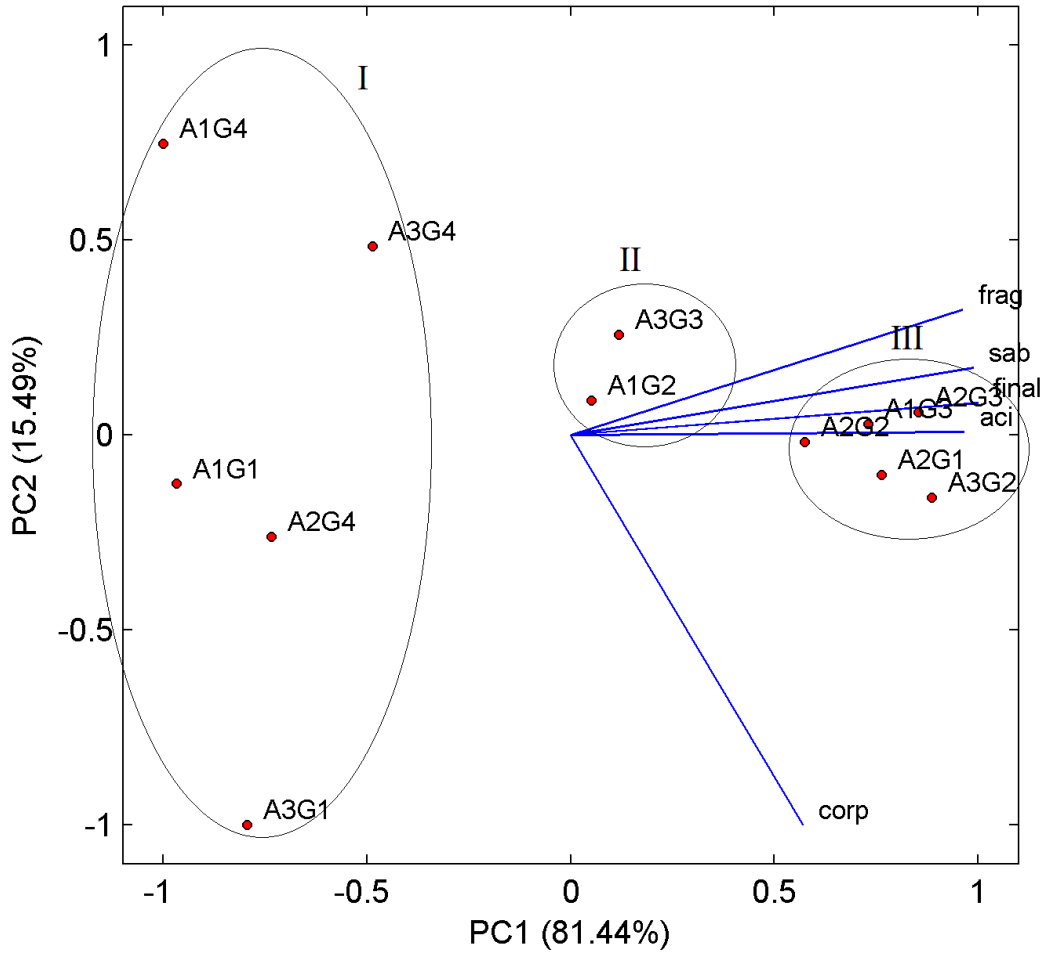

Figure 1. Principal component analysis biplot of PC1 and PC2 for the dataset of four genotypes (G) and three environments (A) as functions of the sensory attributes and the final sensory score. frag=fragrance; sab=taste; aci=acidity; corp=body; final= final sensory score. G1: Mundo. Novo IAC 502/9, G2: 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.

in the organic acids analyzed (Table 3). The sucrose content in commercial green coffee beans varies according to the coffee species, variety, geographical origin and roasting conditions (Knopp et al., 2006; Oosterveld et al., 2003).

The interaction between genotype and the environment was significant ($P<0.05$) for the sucrose content, final sensory score and most of the attributes analyzed. These results emphasize the effect of the genotype and environmental conditions on the final quality of the coffee beans, as previously reported (Bertrand et al., 2006; Malta and Chagas, 2009).

Principal component analysis (PCA)

The biplots were obtained according to the score dispersion of the first principal components in the axes. The first component showed the highest variance, followed by the second component. The main characteristics that determined the formed groups were also detected from the biplot outputs.

Figure 1 is a projection of the results obtained from the PCA. It refers to the distribution of the genotype/environment (A_xG_y) scores as functions of the sensory attributes and the final sensory score. PC1 and PC2 showed 81.44 and 15.49% of the total variance, respectively, totaling 96.93% of the total variance. This result is an excellent explanation of the variation occurring among the samples regarding their sensory characteristics.

In the biplots shown (Figures 1 and 2), the sensory attributes are represented by vectors and the interaction between genotypes and environments (A_xG_y) are represented by dots. PC1 suggested similarity among the dots (Figure 1), which formed three distinct groups of

Table 4. Correlation values of the assessed parameters (final sensory score and sensory attributes) of the principal component analysis.

Parameter	PC1 (%)	PC2 (%)
Fragrance	0.96	0.32
Taste	0.99	0.17
Acidity	0.97	0.01
Body	0.57	-1.00
Final	1.00	0.08

genotypes x environment: group I (A1G1, A1G4, A3G1, A2G4 and A3G4); group II (A3G3 and A1G2); and group III (A2G3, A1G3, A3G2, A2G1 and A2G2).

Coffee samples belonging to group I showed little relation according to fragrance, taste and acidity and had lower final sensory scores (below 80 points) (Table 3) when compared with group III (Figure 1). All the genotypes that showed scores above 80 had potential for the production of specialty coffees, especially those with scores above 81 points (group III).

Fragrance, taste and acidity were the most important attributes for the discrimination of the coffee samples, which characterize PC1 (Table 4). Acidity in coffee is an important organoleptic parameter, which might be desirable or not, depending on the nature of the predominant acid in the beverage. The desirable acidity contributes to the vivacity of the coffee drink, increasing the sweetness perception and providing a dry fruit taste. An over-expressed acidity may be unpleasant, and it may be related to unusual tastes in coffee drinks (Illy and Viani, 2005; Lingle, 2011).

Body showed higher correlation with PC2. This attribute was important for discriminating the sensory profile of coffee samples with lower sensory scores (group I). Body is an attribute that is used to describe and characterize the physical properties related to density and texture (Avelino et al., 2005; Illy and Viani, 2005).

The genotypes expressed their sensory characteristics in different ways (Figure 1). The Yellow Bourbon genotype (G1) showed lower scores for taste, acidity and fragrance when compared with the Yellow Bourbon genotype IAC J9 (G2) and Yellow Bourbon (G3). The genotype G4 showed the lowest potential for the production of specialty coffees regardless of the environment where it was grown. The G4 samples were located on the opposite side of the vectors that indicate the scores of the attributes. Differences among Bourbon genotype lines regarding the potential for the production of coffees with higher quality has also been reported (Ferreira, et al., 2012; Figueiredo, et al., 2013).

São Sebastião da Grama (A2) was higher when compared with Lavras (A1) and Santo Antônio do Amparo (A3). The A2 environment showed higher scores for the sensory attributes acidity, taste and fragrance (Figure 1) and had the highest final sensory scores (Table 3). Its samples were located at the right side of the biplot (group III), with the exception of genotype G4.

The three studied environments (A1, A2 and A3) are known for their large production of commodity coffees and also for producing specialty coffees. However, even regions propitious for producing specialty coffees have a climatic diversity that causes variation in the beverage (Alves et al., 2011). Variation in climatic conditions may interfere with the formation and maturation of coffee fruits (Dal Molin et al., 2008), which allows differences in the final sensory profile of the beans.

The Mundo Novo cultivar (G1) is widely cultivated in Brazil, mainly because it has a high yield (Carvalho et al., 2006; Fazuoli et al., 2005). However, it has shown restrictions for the production of specialty coffee, which indicates that its beverage is highly dependent on the environment where it is grown. This cultivar only had an outstanding sensory score when grown in São Sebastião da Grama (A2), the most suitable environment for the production of specialty coffee.

The Yellow Bourbon genotype grown in Lavras (A1G3) and the Yellow Bourbon IAC J9 (A3G2) genotype grown in Santo Antônio do Amparo showed outstanding sensory scores and allowed the production of high quality coffees (Figure 1). In this case, the interaction between the genotype and environment was a determining parameter for the flavor expression of the samples. These results confirm the high potential of G2 and G3 for providing specialty coffees under different environmental conditions. Genetic diversity is one of the most important factors that contribute to the definition of the final coffee quality (Dessalegn et al., 2008; Leroy et al., 2006; Pereira, et al., 2010).

Considering studies correlating the chemical composition of green coffee beans with the final sensory quality, a new biplot was generated (Figure 2). It was generated from the PCA of the four genotypes and the three environments in the study, and its variables included sensory attributes, final sensory score, organic acids and sucrose. PC 1 explained 47.91% of the total variance, and PC 2 explained 15.82%. Together, the first two principal components explained 63.73% of the total variance.

The correlation results among organic acids, final sensory score and sensory attributes are represented in Figure 2, and the weight of each variable is shown in Table 5. Figure 2 also shows that the groups of dots previously obtained as a function of the sensory attributes (Figure 1) were similar, although the percentage of the explained variance was lower. The sensory attributes were clearly represented along PC1 in the biplot (Figure 2), with the exception of the body; the chemical variables were represented along PC2, with the exception of oxalic acid and sucrose.

The inclusion of the chemical compounds as variables in the principal component analysis allowed for a higher dispersion of the dots (A_xG_y). An increase in dissimilarity among the genotypes x environments (A_xG_y) was

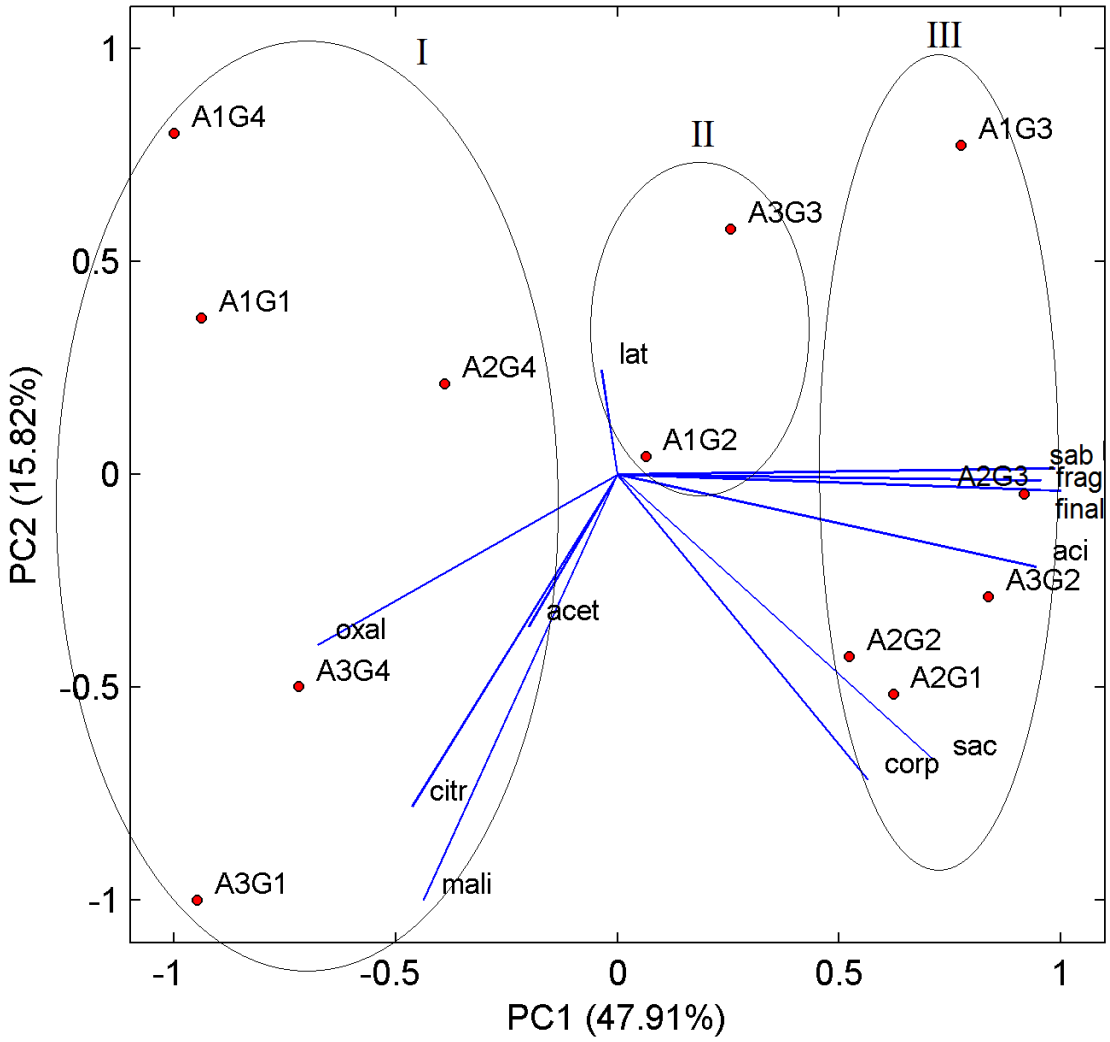

Figure 2. Biplot of principal component 1 (47.91%) and 2 (15.82%) of the principal component analysis of four genotypes (G) and three environments (A). The variables considered for the analysis included organic acids, sucrose, final sensory score and sensory attributes. frag=fragrance; sab=taste; aci=acidity; corp=body; final=final sensory score; lat=lactic acid; oxal=oxalic acid; citr=citric acid; acet=acetic acid; mali=malic acid; sac=sucrose. 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.

observed. This increase in the distance between the samples occurred mainly along PC2, which showed a larger influence of the chemical compounds (Figure 2).

Sucrose and oxalic acid had a higher correlation with PC1 (Table 5), which contributed to the discrimination of groups I and III (Figure 2). The weights of these compounds (value in module) were higher than 0.65, indicating that they were important for the scores on PC1 spreading. Coffees with the best sensory characteristics (group III) were positively correlated with the content of sucrose and negatively correlated with oxalic acid. The opposite behavior was observed for the samples belonging to group I (Figure 2 and Table 5).

Sucrose is a compound that is present in green coffee beans and has been the focus of studies as an important precursor of taste and aroma. This compound is rapidly degraded, and it can be found only in vestigial levels after the coffee is roasted. The decrease in sucrose level may reach 98% during roasting (Trugo and Macrae, 1984). Sucrose is also an important contributor to the formation of reducing sugars that are involved in the fragmentation and caramelization roasting reactions as well as the Maillard reaction. Several compounds resulting from the reactions are important contributors to coffee flavor, which may be related to beverage sweetness (Ginz et al., 2000; Rogers et al., 1999). This sensory attribute is one of the most appreciated characteristics in gourmet coffee drinks. That is why sucrose is expected to be present at higher levels in coffees with higher quality, as was observed in the present study.

Table 5. Correlation between the analyzed variables (organic acids, final sensory score and sensory attributes) in principal components 1 and 2.

Parameter	PC1 (46.52%)	PC2 (26.69%)
Fragrance	0.96	-0.01
Taste	0.99	0.01
Acidity	0.94	-0.22
Body	0.56	-0.72
Final	1.00	-0.04
Lactic acid	-0.03	0.24
Acetic acid	-0.20	-0.36
Malic acid	-0.44	-1.00
Oxalic acid	-0.68	-0.40
Citric acid	-0.46	-0.78
Sucrose	0.72	-0.68

Sucrose content has also been positively associated with coffees with higher acidity (Bertrand et al., 2003; Decazy et al., 2003), which confirms the results of our study. The sucrose vector and acidity attribute showed proximity in the biplot (Figure 2) and a positive correlation pointing to the same group of samples. Those attributes were extremely important in the discrimination of coffee samples A3G2, A2G2 and A2G1, which showed the highest scores in the sensory analysis. Therefore, the contribution of the sweetness and acidity attributes was important for the taste and aroma of the coffee samples.

Oxalic acid is a toxic dicarboxylic acid and is present in plants, such as spinach and wood sorrel. Although, the consumption of pure oxalic acid is deadly, its level in edible plants is very low to present any serious risk (Snyder, 2002). Oxalic acid was the organic acid found in the lowest amount in the samples (average values ~0.05% d. m.). No study in the literature correlates the oxalic acid content with its sensory perception in food. However, its content in this study was negatively related to beverage quality.

The other organic acids (lactic acid, acetic acid, malic acid and citric acid) showed higher weights when contributing to sample dispersion in PC2 (Table 5). Malic acid and citric acid were the organic acids with the highest correlation coefficients in PC2. PC2 allowed for the discrimination of the samples (A_xG_y) as a function of the malic and citric acidS in each group previously formed by PC1.

Carboxylic acids are responsible for coffee fragrance in low concentrations. In addition, each acid has its own taste, e.g., lime taste for citric acid, buttery taste for lactic acid and apple taste for malic acid. Those acids are more perceptible as an odor rather than as a taste. Acetic acid is an exception in coffee because its presence is the result of fermentation in coffee. Green coffee beans, which have high levels of this acid, usually favor a fermented taste, which is very distasteful (Lingle, 2011). It was highlighted that all of the correct procedures for the production of specialty coffees were followed during the harvest and post-harvest of the coffee fruit samples in this study. Such care guaranteed samples free of defects and fermentation.

Although, organic acids are responsible for the formation of taste and aroma in coffee, PC2 explained only 15.8% of the total variance. These results indicated that the quantified organic acids (lactic acid, acetic acid, malic acid and citric acid) may not, by themselves, explain the sensory characteristics assessed.

Conclusions

Yellow Bourbon IAC J9 and Yellow Bourbon/origin SSP were the genotypes most indicated for the production of specialty coffees. This information brings strong insight to breeding programs that are beginning to focus on coffee quality and to farmers that want to develop a business in specialty coffees in Brazil.

Sucrose content and oxalic acid content were found to be good discriminant markers for green coffee beans regarding the final quality of the coffee samples. Conversely, lactic, acetic, malic and citric acids did not allow the discrimination of the coffee samples in relation to their quality.

Conflict of Interests

The authors have not declared any conflict of interests.

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