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CHEMICAL AND SENSORY CHARACTERISTICS IN THE SELECTION OF BOURBON GENOTYPES

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Abstract

The evaluation of coffee quality in Brazil for commercialization is conducted mainly through sensory analysis, also known as the "cup test", in which professional tasters evaluate and score various attributes. The adoption of chemical methods could complement the sensory classification of beverages, if correlations between these chemical and sensory analyses exist, making classification less subjective. This work aimed to identify the relationships between the chemical and sensorial traits of coffee-beverage quality and to evaluate the use of these traits as criteria for the selection of Bourbon cultivars. Twenty coffee genotypes from the first three harvests across five municipalities of the state of Minas Gerais, Brazil were evaluated. The genotypic values, predicted for each genotype, were used to determine the index based on the sum of ranks from Mulamba and Mock. The genetic correlations among the evaluated traits were also estimated. The presented evaluations were not able to efficiently detect genetic and phenotypic relationships between the chemical and sensorial characteristics of drink quality, but as selection criteria for generation advancement in the beverage quality, it is possible to use these characteristics. Bourbon Amarelo LCJ 9-IAC, Bourbon Amarelo-Procafé, Bourbon Amarelo-Boa Vista, Bourbon Vermelho-São João Batista, and Bourbon Amarelo-Samambaia were the genotypes with the most promising cup quality in the studied regions. Through the selection of these five genotypes, the selection gain was 1.65% for sensory score for beverage quality, when the interaction among the studied environments was removed. The heritability was 92% for improving this trait.

Keywords: BLUP. *Coffea arabica*. Genetic correlation. Genetic improvement. Simultaneous selection.

1. Introduction

Given the change in the profile of coffee consumers associated with greater demand in the specialty coffee market, it is necessary to identify genotypes that present aptitude for the production of differentiated coffees. For this reason, researchers have been emphases beverage quality in the development of new coffee cultivars (Figueiredo et al. 2013; Sunarharum et al. 2014).

Arabica coffee is known for producing brews with high cup quality. However, the chemical composition, is affected by a range of parameters, including cultivar, planting origin, harvest method, type of preparation, grain appearance, among others, that may condition a pleasant sensory profile in the cup (Toledo et al. 2016; Fassio et al. 2020). The Bourbon is a variety of the species *Coffea arabica*, which is known for its sensory characteristics making it prized and desirable in the specialty coffee industry (Figueiredo et al. 2013). This group of varieties produces high-quality beans for use in specialty coffees in diverse regions of the world (Flambeau et al. 2017; Steen et al. 2017).

The sensory evaluation for commercialization is conducted mainly through physical examination and sensory analysis, also known as the "cup test", in which professional tasters evaluate and score various attributes (Pimenta et al. 2018). However, this process can lead to distortions, causing disagreement between samples tested by different tasters. The adoption of chemical analyses could complement the sensory classification of beverage, making classification less subjective, if correlations between the sensory and chemical trait analyses exist. There are few studies to date that correlate the physicochemical and sensory attributes of coffee and that use multivariate tools to understand coffee flavor (Farah et al. 2006; Alves et al. 2018).

The selection of a set of important characters is necessary, aiming at adequate gains, simultaneously, in all characteristics in the breeding programs (Ashikaga et al. 2016). Selection indices are multivariate techniques that associate information related to various traits of agronomic interest with the genetic properties of the evaluated population. The index by Mulamba and Mock (1978) based on the sum of the rankings provides a simultaneous selection of gains in several situations. Furthermore, the mixed model method (Henderson 1984) is a procedure that allows obtaining estimates of genetic values and parameters and maximizes genetic gains with selection (Salgado et al. 2014; Arendacká and Puntanen 2015). Studies involving these procedures can contribute significantly to genetic improvement and, consequently, reduce the time spent in obtaining cultivars with better cup quality.

The aims in this work were i) to identify the relationships between the chemical and sensorial traits of coffee-beverage quality and ii) to evaluate the use of chemical and sensorial traits as a criterion for selection of Bourbon coffee variety.

2. Material and Methods

The experiments were conducted in two important coffee regions of the state of Minas Gerais (southern Minas Gerais and Alto Paranaíba) to represent the environmental conditions existing in regions known to produce fine coffees. The municipalities of Campos Altos, Santo Antônio do Amparo, Patrocínio, Lavras and, Três Pontas were selected (Table 1). The soils in all the selected regions were classified as Dystroferric Red Latosol.

Table 1. Geographic region, climatic variables and, characterization of the experimental installation sites in the state of Minas Gerais.

Municipalities	Locations	Altitude	Temperature*	Precipitation*	Coordinates
Campos Altos	Alto Paranaíba	1,230 m	17,6°C	1,830 mm	19°41’46”S 46°59’33”N
Santo Antônio do Amparo	South of Minas	1,050 m	19,8°C	1,670 mm	20°56’47”S 44°55’08”O
Patrocínio	Alto Paranaíba	966 m	22°C	1,620 mm	18°56’38”S 46°59’33”N
Lavras	South of Minas	950 m	19,3°C	1,529 mm	21°14’43”S 44°59’59”O
Três Pontas	South of Minas	905 m	18°C	1,545 mm	21°20’50”S 45°28’23”O

*Annual averages.

There were evaluated twenty coffee genotypes obtained from different farms that had their products well rated in drinking quality contests. These farms are located in traditional coffee growing regions but have no records of the origin of cultivars that were originally planted. Therefore, the cultivars were denominated by the name of the farm: Bourbon Amarelo LCJ 10-Epamig de Machado (BA1), Bourbon Amarelo-Procafé

(BA2), Bourbon Amarelo-Bom Jardim (BA3), Bourbon Amarelo-Betânia (BA4), Bourbon Amarelo-Boa Vista (BA5), Bourbon Amarelo LCJ 9-IAC (BA6), Bourbon Amarelo-Toriba (BA7), Bourbon Amarelo-São Paulo (BA8), Bourbon Amarelo-Castro (BA9), Bourbon Amarelo-Nogueira (BA10), Bourbon Amarelo-Paixão (BA11), Bourbon Amarelo-Samambaia (BA12), Bourbon Vermelho-Procafé (BV13), Bourbon Vermelho-São João Batista (BV14), Bourbon Amarelo Italiano-Monte Alegre (BA15), Bourbon Amarelo Trigo- Monte Alegre (BA16) and Bourbon Amarelo Limoeiro-Monte Alegre (BA17). The cultivars Mundo Novo IAC 502/9 (S18), Catuaí Vermelho IAC 144 (S19) and Icatu Amarelo IAC 3282 (S20), which are widely cultivated throughout the state of Minas Gerais, were used as standards in the trials.

A randomized complete block design was used, which included three replicates and plots consisting of 10 plants, of which the six central plants were used. The adopted spacing was 3.5 m between rows and 0.70 m between plants (4,081 plants ha^{-1}).

The analyses of chemical and sensorial attributes were performed annually during the first three harvests. After careful harvesting, the fruits in the cherry stage and the dried fruits were separated based on density of fruits in a water box and a sieve made of 3.0 mm x 3.0 mm wire mesh.

The separation of fruits in the cherry stage from those in the green stage, which may have remained in the sample, was performed with the aid of a coffee peeler, which, by means of pressure exerted on the fruits, allowed only the ripe fruit to be peeled. Using this method, seven liters of peeled cherry coffee was obtained. These samples were uniformly distributed in 1 m^2 sieves (with a wooden frame and a mesh screen of 2.00 x 1.00 mm, made of polyethylene wires), where they were rotated 12 times per day until the coffee beans reached a moisture content of approximately 11% (wb). After drying, the samples were organized and prepared for the chemical and sensorial analyses.

The processed samples were frozen in liquid nitrogen and ground using IKA A11 Basic Analytic® mill, sprayed and kept at -80 °C for further analysis of total titratable acidity (ATT), reducing sugars (AR), nonreducing agents (ANR), potassium ion leaching (LK), electrical conductivity (CE), soluble solids (SS), total chlorogenic acids (ACT) and total phenolic compounds (CPT). These analyses were performed in triplicate and the data were expressed in g 100 g^{-1} (d.b.).

The CE and the amount of LK were determined according to a methodology proposed by Prete and Abrahão (1995), with a samples soaking time of five hours. The acidity was determined by titration with 0.1 N NaOH according to a technique described by the AOAC (1990) and expressed in ml of 0.1 N NaOH per 100 grams sample. The sugars were extracted by the Lane-Enyon method, as described by the AOAC (1990), and determined by the Somogy technique as modified by Nelson (1944). To determine the SS, the grains were crushed, water was added and then the mixture was filtered as described by AOAC (1990). The amount of ACT was determined according to Abrahão et al. (2008). The CPT were extracted by the method of Goldstein and Swain (1963) and quantified by the method of Folin Denis (AOAC 1970).

For sensory analysis, a panel of three trained judges (Q-grader) evaluated five cups of each sample in relation to eight attributes, clean cup (Ccp), sweetness (Swt), acidity (Acd), body (Bod), flavor (Fla), aftertaste (Aft), balance (Bln), and overall impression (Ove), and each attribute was assigned a score ranging from 0–8 based on the intensity of the sample, thus ensuring greater objectivity than conventional "cup tests". The sum of the attribute scores represented the final score of beverages (Fsc), allowing for the final classification of the drink. Each sample began with a pre-established score of 36 points, which incorporated the notes of each attribute, and samples with a score higher than 80 were classified as specialty coffee (Carvalho et al. 2016).

The averages of quality attributes of first three harvests of each crop were used in the statistical analyses. The data obtained were adjusted to the following linear mixed model:

$$y = Xr + Zg + Wb + e,$$

which y is the data vector; r is the fixed-effects vector of the measurement-replication combinations added to the general mean; g is the vector of the genotypic effects N (0, $A\sigma_g^2\sigma$), which A is the kinship matrix and $\sigma_g^2\sigma$ is the genotypic variance; b is the vector of the effects of blocks N (0, $I\sigma_b^2\sigma$), which I is the identity matrix and $\sigma_b^2\sigma$ is the environmental variance between blocks; e is the vector of errors or residues N (0, $I\sigma_e^2\sigma$), where $I\sigma_e^2\sigma$ is the residual variance; and X, Z, W are the incidence matrices for the effects r, g and b, respectively.

Estimates of the genetic parameters were obtained by the REML/BLUP (restricted maximum likelihood/best linear unbiased prediction) procedure using the SELEGEN-REML/BLUP computational software (Resende 2016). The evaluation of the variances associated with the random effects were made using the likelihood ratio test at p<0.01 and p<0.05.

The genotypic values, predicted for each genotype, were used to determine the index based on the sum of ranks from Mulamba and Mock (1978). The genetic correlations among the evaluated traits were also estimated using the Genes program (Cruz 2013).

3. Results

The correlations between AR and ATT, CE and ATT, AR and Fsc as well as Fsc and CE were negative (Figure 1). These correlations were significant, but coefficients varying between 0.35 and 0.48. Therefore, they are not mentioned in the discussion. The characteristics AR and CE, RA and CPT, Fsc and ATT, and LK and CPT presented positive correlations of moderate to high magnitude, between 0.60 and 0.89.

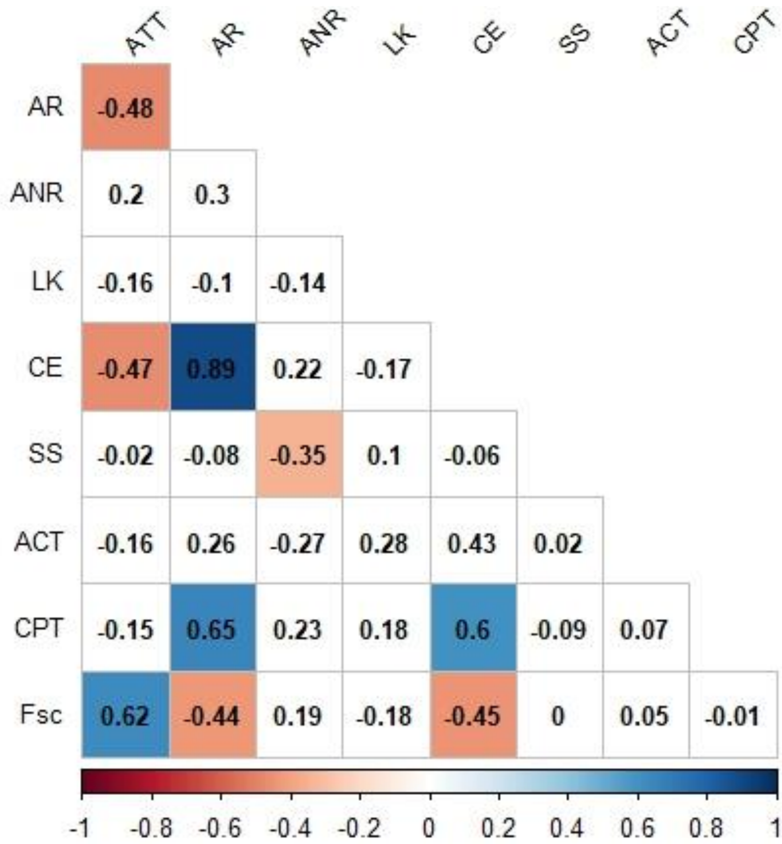

Figure 1. Pearson correlation matrix of the studied variables, including titratable total acidity (ATT), reducing sugars (AR), nonreducing sugars (ANR), potassium ion leaching (LK), electrical conductivity (CE), soluble solids (SS), total chlorogenic acids (ACT), total phenolic compounds (CPT) and final drink score (Fsc).

The genotype variance indicates the possibility of selection for the ATT, ANR, LK, and Fsc characteristics (Table 2). The heritability estimates obtained for Fsc indicate that this trait can be selected for with high accuracy of 96% and reflected the quantity and quality of information and the procedures used in the prediction of genetic values. The ATT, ANR and LK characteristics presented moderate accuracy magnitudes varying from 49% to 66%. The genotypic correlation in environments was 83 and 99%, respectively, for the characteristics LK and Fsc indicating the agreement of the best progenies in the five evaluation municipalities. The observed values of the coefficient of determination due to the effects of the genotype x local interaction were 0.09 for the ATT and 0.29 for SS characters, values compatible with experiments considered accurate by Freitas et al. (2007).

Table 2. Estimates of the genotypic parameters related to titratable total acidity (ATT), reducing sugars (AR), nonreducing sugars (ANR), potassium ion leaching (LK), electrical conductivity (CE), soluble solids (SS), total chlorogenic acids (ACT), total phenolic compounds (CPT) and final score of beverage (Fsc).

Parameters	ATT	AR	ANR	LK	CE	SS	ACT	CFT	Fsc
v_g	4.73*	0.05	15.84*	4.09*	0.01	6.33	0.01	6.03	4.20*
c^2_{int}	0.29	0.01	0.03	0.01	0.01	0.09	0.01	0.03	0.00
Ac_{gen}	0.66	0.11	0.49	0.53	0.10	0.30	0.11	0.31	0.96
h^2_{mg}	0,43	0,01	0,24	0,28	0,01	0,09	0,01	0,10	0,92
rg_{loc}	0.21	0.07	0.40	0.83	0.04	0.08	0.09	0.19	0.99
Average	205.37	5.75	75.74	26.91	72.36	46.31	7.91	34.86	83.39

*Significant at 5% as determined by the likelihood ratio test. v_g Genotype variance, c^2_{int} coefficient of determination for the effects of genotype x local interaction, h^2_{mg} heritability of genotype average, assuming complete survival, Ac_{gen} accuracy of genotype selection, assuming complete survival, rg_{loc} genotype correlation between performance in environments.

The choice of ATT, ANR, LK, and Fsc for selection of progenies was based on genotypic parameters. The progenies BA6, BA2, BA5, BA14, and BA12 were more promising for this characteristic (Table 3). The selection of these genotypes was based on the ability of characteristics to be simultaneously selected as described by Mulamba and Mock (1978). None of cultivars used as standards were among the genotypes selected (Table 3). The predicted genotypic values indicated improvement over the genotypic mean of each characteristic, with a 1.65% increase in Fsc, 0.38% increase in ATT, 1.26% increase in ANR, and 1.11% reduction in LK.

Table 3. Estimates of average components using the BLUP procedure. The predicted additive genetic value (û + â) values related to the Mulamba and Mock (1978) index (Ij) related to titratable total acidity (ATT), nonreducing sugars (ANR), potassium ion leaching (LK), and final score of beverage (Fsc).

Parameters	ATT	ANR	LK	Fsc	
Genotypes	û + â	û + â	û + â	û + â	Ij
BA1	205.79	74.94	74.94	85.66	24.53
BA2	205.79	75.58	75.58	84.73	26.18
BA3	205.21	73.15	73.15	85.66	28.32
BA4	206.36	74.38	74.38	84.59	25.72
BA5	206.51	75.66	75.66	85.27	26.88
BA6	206.51	78.24	78.24	86.61	25.95
BA7	204.06	74.59	74.59	83.89	27.64
BA8	205.38	77.41	77.41	84.81	27.30
BA9	206.22	76.64	76.64	84.24	26.12
BA10	206.65	72.16	72.16	82.08	27.77
BA11	205.50	73.34	73.34	81.41	26.54
BA12	207.52	77.39	77.39	84.32	26.27
BA13	206.22	78.28	78.28	84.75	28.80
BA14	204.49	76.67	76.67	82.94	27.77
BA15	203.77	76.00	76.00	80.59	26.43
BA16	203.19	74.30	74.30	80.40	28.04
BA17	203.05	78.72	78.72	80.52	25.70
S18[1]	202.33	73.09	73.09	80.77	27.36
S19[1]	206.94	77.10	77.10	82.30	26.79
S20[1]	205.93	77.25	77.25	82.30	28.15
Average	205.37	75.74	26.91	83.39	
GS%[2]	0.38	1.26	-1.11	1.65	

[1]Cultivars used as standards. Overall average of the experiment. [2]Predicted additive genetic gain considering the genotypes BA6, BA2, BA5, BA14, and BA12.

4. Discussion

In order to know the associations of inheritable nature to be used in the orientation of breeding programs aiming at coffee-beverage quality, the genotypic correlation between the characteristics studied was estimated (Figure 1). ATT had a favorable effect on Fsc, indicating that acids not only contribute to sourness of coffee-beverage quality, but also appear to be important factors in determining particular flavor, and aroma of beverage (Clemente et al. 2015). AR was highly correlated with content of CE. This occurs, due the membrane degeneration, caused by possible fermentation due to sugars present in the bark, resulted in aggregation of leached electrolytes and coffee-beverage quality (Caixeta et al. 2013). The CPT showed a correlation with CE, and also with AR, which corroborates the findings of other authors (Chagas and Malta 2008). Phenolic components refer to flavonoids, phenolic acids, and phenolic diterpenes and have antioxidative effects that retard oxidative degradation of lipids and thereby improve the quality and nutritional value of food (Javanmardi et al. 2003).

The correlations observed in this work suggest that the chemical analyses of total titratable acidity and electrical conductivity do not aid in the identification of genotypes that result in a specialty beverage. Instead, these correlations demonstrate that titratable acidity and electrical conductivity activities are related to processes that respond to grain damage (Taveira et al. 2015), resulting in a measurable loss of quality that was not representative of a change in the appearance of grains. Despite the wide application of chemometrics, correlating compositional data with sensory attributes is a complicated task (Sunarharum et al. 2014). Under optimal harvesting and post harvesting processes, as in the present work, these chemical evaluations may not be able to detect relationships between the chemical and sensorial quality characteristics of the beverage.

The implemented analysis allowed the simultaneous estimation of genotype mean heritability and genotype correlation between performance in environments. It also allowed identifying progenies coffee-beverage quality confirmed genetic gain, and, thus, supported our hypothesis of the use of chemical and sensorial traits as a selection criterion.

The genetic gain is inversely proportional to intensity of selection, which determines the number of selected individuals. Thus, in the present study, the need to work with a large number of individuals (five genotypes, 25% selection intensity) to ensure a minimum effective number that, according to Rocha et al. (2009), allows greater efficiency in the subsequent selection stages was considered (Table 3).

When aiming for the beverage quality ideotype, superior genotypes for all characteristics studied are sought. The simultaneous selection criteria applied to the genetic values favored positive genetic gains in the collection of genotypes Bourbon Amarelo LCJ 9-IAC, Bourbon Amarelo-Procafé, Bourbon Amarelo-Boa Vista, Bourbon Vermelho-São João Batista and Bourbon Amarelo-Samambaia for indicating the potential use of these cultivars for the advancement of generations. Similarly, Ferreira et al. (2012), analyzed the sensory beverage quality of these genotypes and determined that the genotype Bourbon Amarelo LCJ 9-IAC had the greatest potential for the production of specialty coffees in the five environments studied.

The selected five genotypes had scores between 82 and 86 (Table 3). In order for a coffee to be classified as a specialty coffee, its score should be higher than 80 (Chalfoun et al. 2013). Their genetic potential to produce specialty coffees is clear, as determined by predicted additive genetic value. These genotypes can be used for production of coffee targeting a different market from commodity coffee and meeting the demand of specialty coffee growers and buyers.

In this study, we proposed ways to improve coffee-beverage quality plant selection. Five genotypes with quality aptitude showing selection gain of 1.65% for sensory score for beverage quality were selected. It is also worth noting the possibility of improving the final drink through the selection of these five genotypes; when the interaction among the studied environments was removed, there was 92% heritability for improving sensory score for beverage quality (Table 2).

We reinforce the superiority of BA14 genotype which was previously evaluated in field conditions by Ferreira et al. (2013). This genotype has desirable agronomic characteristics, and also stability and adaptability in different environments. The superior genotypes identified are promising options for integration into coffee breeding programs focused on quality and should be selected by the breeder considering the overall need for desired traits.

5. Conclusions

The presented evaluations were not able to efficiently detect genetic and phenotypic relationships between the chemical and sensorial characteristics of drink quality, but as selection criteria for generation advancement in the beverage quality, it is possible to use these characteristics. Bourbon Amarelo LCJ 9-IAC, Bourbon Amarelo-Procafé, Bourbon Amarelo-Boa Vista, Bourbon Vermelho-São João Batista, and Bourbon Amarelo-Samambaia were the genotypes with the most promising cup quality in the studied regions. Through the selection of these five genotypes, the selection gain was 1.65% for sensory score for beverage quality, when the interaction among the studied environments was removed. The heritability was 92% for improving this trait.

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