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Quality of coffee produced in the Southwest region of Bahia, Brazil subjected to different forms of processing and drying

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Coffee quality is vital for quoting prices, marketing and for the acceptance of the final product by the consumer market. Many factors can interfere with the quality of the coffee beans, especially those related to the stages of post-harvest, such as processing and drying. The objective of this study was to evaluate the influence of dry (natural) and wet (washed) processing, dried in an earthen yard and in a cement yard, respectively, on the physico-chemical composition and quality of coffee beans produced in the southwest region of Bahia, in the 2007/2008 harvest season. The present study evaluated the parameters of pH, electrical conductivity, potassium leaching, total sugars, non-reducing sugars, reducing sugars, caffeine, total titratable acidity, soluble solids, sensory analysis and the pH of the infusion of roasted and ground coffee beans which resulted from natural and washed processing in the municipalities of Barra do Choça and Encruzilhada, in the southwest region of Bahia. It is suggested by the results obtained that, for the southwest region of Bahia, washed processing associated to the drying of the beans in a concrete yard provides coffees of a better quality when compared with the naturally processed beans dried in an earthen yard.

Key words: *Coffea arabica*, physico-chemical composition, post-harvest.

INTRODUCTION

Coffee is an agricultural product whose price is based on qualitative parameters and varies significantly depending on the quality presented (Malta et al., 2008). Coffee quality is directly related to the various physical and physico-chemical constituents of the raw beans, which are responsible for the appearance of the roasted coffee beans, for the beverage's flavor and its distinctive aroma (Pimenta, 2003). The chemical components in the coffee beans define the quality of the beverage, both from a sensory and a consumer health standpoint (Salva and Lima, 2007). The existence of correlations between cup tastings and the attributes of raw and toasted beans indicate that the chemical analysis of raw beans can be used as an additional tool for evaluating coffee quality

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(Farah et al., 2006).

The final quality of coffee is influenced by several factors, such as: Cultivars (Lopes et al., 2000), cultivation site (Lima et al., 2011; Silva et al., 2009), crop fertilization (Malta et al., 2003a; Silva et al., 2002), harvest (Pimenta and Vilela, 2002) and post-harvest processing (Nobre et al., 2011; Lima et al., 2008). The selection of the post-harvest processing method is crucial for the profitability of the coffee production and it depends on factors such as the cost-benefit ratio, the need to comply with environmental legislation and the desired standard for product quality. Historically, two different methods are used for coffee processing: The dry-processing and the wet processing (Borém, 2008). In Brazil, despite the increasing use of post-harvest preparation of coffee through wet processing (peeled, washed and demucilaged), the traditional system (dry processing) is predominant. The traditional system sees coffee dried using one of two methods: The more common method sees coffee dried completely in yards, or alternatively the coffee is partially dried in yards and finished using mechanical dryers (Silva et al., 2008). Therefore, to ensure a product of higher quality and better profitability, post-harvesting care and techniques are essential (Malta et al., 2008).

In the southwest region of Bahia, the traditional post-harvesting handlings of coffee employed are the dry processing (natural), in which most of the drying of the coffee production is carried out in earthen yards, located in regions of semi-arid climate and the wet processing, represented mainly by the pulping method, with beans dried in cement yards.

Thus, the objective of the present study was to evaluate the physico-chemical composition of the beans and the sensory quality of coffee as a result of the methodology of the drying process. The processes employed in the southwestern Bahia municipalities of Barra do Choça and Encruzilhada were looked at: The dry or natural process where the beans are dried in earthen yards and the wet or washed process where the beans are dried in cement yards were analysed.

MATERIALS AND METHODS

Coffee bean samples (*Coffea arabica* L.) were obtained at different coffee properties from the southwestern Bahia municipalities of Barra do Choça and Encruzilhada. Ten samples of processed coffee from natural processing (dry), dried in earth yard, and another ten samples from washed processing (wet), dried in cement yard were collected, a total of 20 samples.

Each sample consisted of approximately 1.0 kg of processed coffee beans from the 2007/2008 harvest season. The analyses of the physico-chemical composition and chemistry of the coffee beans were performed in the Laboratory for Coffee Quality “Dr. Alcides Carvalho”, located in the Minas Gerais Agricultural Research Corporation- EPAMIG, in Lavras – Minas Gerais. The grain samples, free of faults, were grounded for about a minute in a TE 631/2 grinder model, of the Tecnal brand, and then placed in plastic packages, which were stored in a freezer at a temperature of -18°C, until the time of analysis. The following parameters were evaluated: pH, electrical conductivity, potassium leaching, total sugars, non-reducing sugars, reducing sugars, caffeine, total titratable acidity and soluble solids.

The pH was determined using a digital ph meter, of the pH DIGIMED-DMPH-2 brand. Electrical conductivity and potassium leaching, expressed in $\mu S.cm^{-1}.g^{-1}$ sample e $mg.kg^{-1}$, respectively, were determined according to the methodology described by Prete (1992). For both cases, 50 coffee beans were used, with a soaking time of five hours.

Sugars were extracted by the Lane-Enyon method, as quoted by AOAC (1990), and determined by the Somogy technique, adapted by Nelson (1944). Results were expressed as percentages. Caffeine was determined according to the methodology of Li et al. (1990). Results were expressed as percentages.

Total titratable acidity was determined by titration with NaOH 0.1 N, according to the AOAC methodology (1990), adapted for coffee by Carvalho et al. (1994). Results were expressed in ml of NaOH 0.1 N. 100 g^{-1} sample.

Soluble solids were determined in a benchtop refractometer, according to the AOAC standards (1990). Results were expressed as percentages.

Sensory analysis was performed at the Coffee Grading, Tasting and Marketing sector of the Cooperativa Mista Agropecuária Conquistense – COOPMAC, in Vitória da Conquista, BA. Coffee tasting was performed by four qualified and experienced tasters, according to the methodology proposed by the *Brazil Specialty Coffee Association* (BSCA), which is considered to be more accurate than the conventional cup tasting. The attributes evaluated were clear beverage, sweetness, acidity, body, taste, remaining taste, balance and overall aspect, with each receiving a grade from 0 to 8, according to the intensity presented in the samples.

The pH of the infusion of roasted and ground coffee beans was evaluated at the Southwestern Bahia State University Grading and Tasting Laboratory– UESB, in Vitória da Conquista, BA, using a digital pH meter, from the Adamo brand, considering the same methodology used to prepare the sensory analysis samples.

Experimental design was completely randomized (DIC), with four treatments: (a) Natural coffee from Barra do Choça; (b) Natural coffee from Encruzilhada; (c) Washed coffee from Barra do Choça; (d) Washed coffee from Encruzilhada, and five repetitions. Statistical analysis was performed for the physico-chemical and chemical factors evaluated, proceeding with variance analysis and the treatment averages comparison performed by the Bonferroni t test at 5% probability; and for the sensorial attributes there was employed a variance analysis, being the treatment averages submitted to comparison by the Scott-Knott test at 5% probability, both using the 5.3 SISVAR statistical program (Ferreira, 2008).

RESULTS AND DISCUSSION

The results for pH, electrical conductivity and potassium leaching are presented in Table 1. When analyzing the pH it is possible to verify that there were no differences between the processes, which presented close values. Chagas et al. (1996) found no significant difference between the coffee samples analyzed, having found average pH values close to 5.5. According to Lima et al. (2008), natural and washed coffee presented, in general, lower bean pH values when compared to the peeled cherry processing. These authors explain that during the preparation of washed coffee, fermentation occurs in the degumming tank and this can lower the pH of the beans. In natural coffee the low pH must have been occasioned by the long drying period of about 15 days,

Table 1. Average values for pH, electrical conductivity (µS.cm^{-1}.g^{-1} of sample) and potassium leaching (mg.kg^{-1}) of coffees resulting from natural and washed processing from the municipalities of Barra do Choça (BC) and Encruzilhada (EN), Southwestern Bahia. 2007/2008 harvest season.

Processing	pH	Electrical conductivity	Potassium leaching
Natural BC	5.64[a]	171.80[a]	33.24[a]
Natural EN	5.65[a]	177.86[a]	36.44[ab]
Washed BC	5.74[a]	180.38[a]	39.48[b]
Washed EN	5.70[a]	176.96[a]	42.18[b]
CV (%)	2.33	4.28	7.79

*Averages followed by the same lower case letter in the column do not differ from each other by the Bonferroni t test at 5% probability (P<0.05%).

Table 2. Average values for total sugars (%), non-reducing sugars (%) and reducing sugars (%) from natural and washed processed coffees from the municipalities of Barra do Choça (BC) and Encruzilhada (EN), Southwestern Bahia. 2007/2008 harvest season.

Treatment	Total sugars	Non-reducing sugars	Reducing sugars
Natural BC	7.39[a]*	6.55[a]	0.49[b]
Natural EN	8.13[a]	7.19[ab]	0.56[b]
Washed BC	8.06[a]	7.44[b]	0.22[a]
Washed EN	8.26[a]	7.49[b]	0.37[a]
CV (%)	5.66	5.65	26.04

*Averages followed by the same lower case letter in the column do not differ from each other by the Bonferroni t test at 5% probability (P<0.05%).

which may cause undesirable fermentation to the beans, especially when weather conditions are unfavorable to the drying process.

Regarding the values of electrical conductivity, no significant differences were found between treatments, with values ranging from 171.80 to 180.38 µS.cm^{-1}.g^{-1} of sample. According to these results, it is suggested that both processing forms used presented a similar behavior. These results are corroborated by Malta et al. (2003b), who found that both the coffee that was dried in its whole form and the coffees that underwent some form of pre-processing presented similar cellular integrity, thereby noting that there was no significant difference in electrical conductivity between the methods of preparation. However, Lima et al. (2008), proceeding selective harvesting and drying of beans in a suspended yard, report that both washed and peeled cherry coffee presented the lowest values of conductivity and potassium leaching when compared to natural coffee, indicating that the processing of the coffee through the wet method maintained the integrity of the beans' cell membranes, while the dry processing method caused the most damage to the cell membranes.

Natural coffee from Barra do Choça presented, in overall average, the lowest value for potassium leaching (33.24 mg.kg^{-1}) and did not differ from the natural coffee from Encruzilhada (36.44 mg.kg^{-1}). Washed coffee from Barra do Choça and Encruzilhada presented, in overall average, the highest values of potassium leaching, 39.48 and 42.18 mg.kg^{-1}, respectively, and also do not significantly differ from the natural coffee from Encruzilhada. Overall, it is noted that the washed coffees presented higher potassium leaching, in contrast with the results observed by Lima et al. (2008).

As the natural coffees presented here were dried in earthen yards, just as is traditionally done in the region, it is inferred by the results from electrical conductivity and especially from potassium leaching, that this drying system did not affect the cellular integrity of the coffee beans.

Electrical conductivity and potassium ions leaching are parameters which serve as an indicator of coffee quality and show a close relationship with the integrity of the cell wall of the grains (Pimenta, 2003). According to Prete (1992), these parameters are strikingly influenced by the defects of black beans, green beans, sour beans and beans affected by other external factors such as insect activity, all of which contribute to cell membrane degradation. The results for total sugars, non-reducing sugars and reducing sugars are presented in Table 2.

The total sugars content did not differ between the analyzed treatments and the values obtained ranged from 7.39 to 8.26%. Total sugars are constituted by reducing sugars, such as glucose and fructose, and non-reducing sugars, mainly represented by sucrose (Pimenta, 2003). Pinto et al. (2002) report that total sugars in the raw beans presented significant differences in the quality of coffee beverages. It is important to note that the samples analyzed in the present study had the "hard beverage" classification by the cup tasting.

Regarding the non-reducing sugars contents, it can be observed that there was significant difference between treatments. It is noted that the natural coffee treatment from Barra do Choça presented a lower percentage of non-reducing sugars (6.55%), when compared to the other treatments and did not differ from the natural coffee treatment from Encruzilhada, which presented a 7.19% content. Washed coffees from Barra do Choça and Encruzilhada presented higher contents of non-reducing sugars, of 7.44 and 7.49%, respectively, and did not differ from each other and from the natural coffee treatment from Encruzilhada. According to Illy and Viani (1995), non-reducing sugars can range from 6.8 to 8.0% in the dry matter of Coffea *arabica* raw beans. Knopp et al. (2006) noted that sucrose and other low molecular weight sugars were not affected by the wet and dry processing, in contrast to results observed in the current study. However, Pinto et al. (2002) report that non-reducing sugars contents varied significantly in the raw bean due to the quality of the coffee beverage, with soft and strictly-soft beverages presenting higher contents whereas the hard and rioy beverages presented lower contents. Chagas et al. (1996) noted that non-reducing sugars varied among the analyzed regions and between municipalities in these regions in the state of Minas Gerais.

A significant difference was detected between the parameters for reducing sugars contents. According to Illy and Viani (1995), reducing sugars can vary from 0.1 to 1.0% in the dry matter of *Coffea arabica* raw beans. It is noted that washed coffees presented lower contents of these sugars when compared to natural coffees. Pereira et al. (2001) have also found significant differences in reducing sugars levels between the analyzed processes, with natural cherry coffee presenting higher contents of these sugars when compared to peeled cherry coffee, peeled-demucilaged, semi-demucilaged and floater coffee. This can be explained by the fact that there is a close correlation between the type of post-harvest processing and the content of fructose and glucose (reducing sugars). According to Knopp et al. (2006), the quantitative analysis of reducing sugars in raw coffee beans revealed that coffees that were prepared through dry processing had relatively higher contents than wet processed coffees, corroborating the results found in this study.

In agreement with the previously mentioned information, Kleinwächter and Selmar (2010) report a steep decrease in fructose and glucose contents in the first day of coffee drying through wet processing. This proves that the lower content of these sugars in such processing, when compared to coffees processed through the dry process, is due to metabolic processes occurring in the grains. In wet processing (washed), oxygen concentration in the degumming tank decreases rapidly due to microbial action, with the decrease in fructose and glucose content being therefore a consequence of anaerobic fermentation in the coffee's endosperm. In contrast to wet processing, dry processed coffee remains in a well ventilated environment during drying, in which a respiratory metabolism of the grains can be maintained while water content is reduced, leading to a virtual closure of metabolic activity (Knopp et al., 2006).

The results for caffeine, total titratable acidity and soluble solids are presented in Table 3. Caffeine contents did not differ significantly between treatments, with the values found being consistent with the limits reported by Prete (1992) of 0.6 to 1.5% for the *C. arabica* species. The results also corroborate Duarte et al. (2010) who found no significant difference in caffeine content between the wet and dry processing methods. However, Teixeira et al. (2012) identified variations in caffeine content between different accessions of *C. arabica*. The uniformity of the data obtained for the caffeine content, in this study, can then be suggested by the genetic factor, since the species of coffee grown in the southwestern region of Bahia is *C. Arabica*, with predominance of the Catuaí cultivar.

For total titratable acidity, there was no significant difference between treatments, which presented similar results regardless of processing and place of origin. Titratable acidity in coffee beans can vary depending on the levels of fermentation occurring in the grains and also with their various maturation stages, serving as an auxiliary analysis to evaluate the quality of the coffee (Malta et al., 2002). According to the results obtained, it is assumed that the climatic conditions of the southwest region of Bahia were not unfavorable for drying the beans in earthen yard, since the acidity values were similar in both forms of processing studied.

Chagas et al. (1996) found no significant differences for total titratable acidity in the studied regions, with the lowest value found being 206.28 ml of NaOH.100 g^{-1} per sample and the highest value of 273.21 ml of NaOH.100 g^{-1}. However, Carvalho et al. (1994) observed significant differences between the levels of total titratable acidity in coffees of different beverage qualities. Regarding soluble solids, significant differences were again not found between treatments that had similar values. The values are, on average is above the range of 24 to 31% proposed by Prete (1992). According to Barbosa et al. (2002), the concentration of soluble solids in coffee beans of different qualities of beverage did not differ significantly.

The results for sensory attributes are presented in Table 4. Regarding sensory analysis, there was a significant difference between treatments for most attributes evaluated, with washed coffee being superior to natural coffees, except for the sweetness attribute. It

Table 3. Average values for caffeine (%), total titratable acidity (ml NaOH 0.1 N.100g^{-1} of sample) and soluble solids (%) of coffees from the municipalities of Barra do Choça (BC) and Encruzilhada (EN), Southwestern Bahia utilizing the natural and washed processes. 2007/2008 harvest season.

Treatments	Caffeine	Total tritable acidity	Soluble solids
Natural BC	1.03^{a*}	190.00^{a}	33.00^{a}
Natural EN	1.13^{a}	190.00^{a}	31.00^{a}
Washed BC	1.15^{a}	190.00^{a}	31.50^{a}
Washed EN	1.10^{a}	185.00^{a}	33.00^{a}
CV (%)	5.99	9.82	5.59

*Averages followed by the same lower case letter in the column do not differ from each other by the Bonferroni t test at 5% probability (P<0.05%).

Table 4. Average values of sensory attributes CB (Clear Beverage), S (Sweetness), A (Acidity), B (Body), T (Taste), RT (Remaining Taste), B (Balance), OA (Overall Aspect) and FS (Final Score) for coffees from natural and washed processing from the municipalities of Barra do Choça (BC) and Encruzilhada (EN), Southwestern Bahia 2007/2008 harvest season.

Treatment	Sensory attributes								FS
	CB	S	A	B	T	RT	B	OA	
Nat. BC	5.18^{b*}	4.93^{a}	5.43^{b}	5.31^{b}	4.93^{b}	5.31^{b}	5.43^{b}	5.56^{b}	78.12^{b}
Nat. EN	4.70^{b}	4.85^{a}	4.90^{b}	5.05^{b}	4.95^{b}	5.05^{b}	5.00c	5.15^{b}	75.65^{b}
Washed BC	5.75^{a}	5.65^{a}	5.85^{a}	6.05^{a}	5.65^{a}	5.95^{a}	6.05^{a}	6.00^{a}	82.95^{a}
Washed EN	5.50^{a}	5.50^{a}	6.00^{a}	6.06^{a}	5.62^{a}	6.00^{a}	6.12^{a}	6.12^{a}	82.93^{a}
CV (%)	8.73	9.98	7.56	5.72	8.35	7.43	5.10	6.31	3.15

*Averages followed by the same lower case letter in the column do not differ from each other by the Scott-Knott test at 5% probability (P<0.05%).

Table 5. Average pH values of the infusion of roasted and ground coffee beans from natural and washed processing from the municipalities of Barra do Choça (BC) and Encruzilhada (EN), Southwestern Bahia 2007/2008 harvest season.

Treatment	Infusion pH
Natural BC	4.94^{a*}
Natural EN	5.03^{a}
Washed BC	4.75^{b}
Washed EN	4.74^{b}
CV (%)	1.19

*Averages followed by the same lower case letter in the column do not differ from each other by the Bonferroni t test at 5% probability (P<0.05%).

should be noted that the washed coffees received a total score that classifies them as specialty coffees, as recommended by the Brazil Specialty Coffee Association (BSCA). Rodarte (2008), when analyzing samples of specialty coffees from peeled cherry and natural processing, found significant difference between these samples for the attributes clean beverage, body, taste and overall aspect, however, differences were found for the attributes sweetness, acidity, remaining taste and balance. According to results from sensory analysis, it can be concluded that dry-processed coffee, coffee dried in earthen yards, presents a better sensory quality than wet-processed coffee, coffee dried in an earthen yard. Pointing out that this processing technology for natural coffee and drying of beans in earthen yards is very usual in the southwest region of Bahia, since many producers make use of it for thinking that climatic conditions of this region favor the drying in this type of yard, and, hence, the production of good quality coffees, contrary to the results observed here.

Coffee quality is directly related to the various physico-chemical constituents of raw beans, which are responsible for the appearance of the roasted bean, the taste and the typical aroma of beverages (Pimenta, 2003). So, when it comes to sensory analysis, the characteristics of the beverage are due to the combination of these beans' constituents (Salva and Lima, 2007). Thus, the results obtained in this study demonstrate that it is possible to obtain coffee with superior quality standards in the conditions of post-harvest adopted in the Southwest region of Bahia, especially through washed processing with the drying of beans in cement yard.

The pH results for roasted and ground coffee beans are presented in Table 5. According to pH results obtained from the infusion of roasted and ground coffee beans, there was a significant difference between treatments, demonstrating that natural treated coffees from Barra do Choça and from Encruzilhada presented higher values compared to washed coffee from these municipalities. According to Fernandes et al. (2003), changes in pH during the roasting can be of great importance in product acceptance by consumers and indicates that the optimal values must be between 4.95 and 5.20, making coffee palatable, without excessive bitterness or acidity.

There were no significant differences between the studied treatments, according to most physico-chemical parameters evaluated. The coffees that underwent wet processing (washed) and were dried in a cement yard, presented higher sensory quality than dry-processed coffees (natural), dried in an earthen yard.

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