QUALITY OF FORESTED AND FULL SUN COFFEE, IN POST-HARVEST MANAGEMENT IN SOUTHWESTERN BAHIA

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ABSTRACT: To summarize aspects related to the physicochemical quality of *Coffea arábica*, cultivated under afforestation and full sun, with both wet and dry post-harvest management, was carried on the present study. The experimental delimitation used was through randomized blocks, in the factorial design 2 x 2 (two cultivation forms – full sun and forested with grevillea and two forms of processing – dry and wet ways), formed of five blocks, totaling 20 portions. The portion was composed, after harvesting and post-harvesting management, by a volume of 10 litres of beans according to the treatment. During harvesting, for each form of cultivation, were evaluated the humid mass, dry mass and the humidity levels in 100 beans. During afterdrying were determined the coffee beans' dry mass and the improved coffee mass. To determine the quality of the coffee, physicochemical analyses were performed. Effects of post-harvest management and cultivation systems were observed in the humid and dry coffee mass characteristics, as well as coffee yield and total titratable acidity. The wet processing increases bean yield and improved coffee mass. Forested coffee presented smaller number of defects, larger reducers and total sugars. The association of trees to the coffee plantations contributed to increase the physicochemical aspects of the beans. The using of wet post-harvesting management increases the physical quality of the coffee.

Index terms: Afforestation, cultivation, *Coffea arabica.*

QUALIDADE DO CAFÉ ARBORIZADO E A PLENO SOL, EM MANEJO PÓS-COLHEITA NO SUDOESTE DA BAHIA

RESUMO: *Para caracterizar aspectos relacionados à qualidade química e física do café arábica, cultivado sob arborização e a pleno sol, com manejo pós-colheita por via úmida e seca, foi desenvolvido o presente estudo. O delineamento experimental utilizado foi em blocos casualisados, no esquema fatorial 2 x 2 (duas formas de cultivo – a pleno sol e arborizado com grevílea e de duas formas de processamento – via seca e via úmida), constituídos de cinco blocos, totalizando 20 parcelas. A parcela foi composta, após colheita e manejo pós-colheita, por volume de 10 litros de frutos de acordo com o tratamento. Na colheita, para cada forma de cultivo, foi avaliado a massa úmida, seca e teor de umidade em 100 frutos. Na pós secagem foi determinada a massa seca do café e massa do café beneficiado. Para a determinação da qualidade do café foram realizadas análises físicas e químicas. Observou-se efeito da interação manejo pós-colheita e sistema de cultivo, nas características massa úmida e massa seca de café, rendimento do café e acidez titulável total. O processamento por via úmida incrementa o rendimento do fruto e a massa do café beneficiado. Cafés arborizados apresentam menor número de defeitos, maiores redutores e açúcares totais. A associação de árvores aos cafezais contribui para melhorar os aspectos físicos e químicos dos grãos. A utilização do manejo pós-colheita por via úmida, melhora a qualidade física do café.*

Termos para indexação: *Arborização, cultivo, Coffea arabica.*

1 INTRODUCTION

Foresting is a largely used technique for coffee protection against weather adversities (CAMARGO, 1998). Arboreal or shrubby component interaction with the biotic and abiotic factors conditions a favorable microclimate, during the juvenile and productive stages of coffee tree, and can ease the stress effects related to the exposure to higher radiation incidence, as well as temperature at under full sun crops (MATSUMOTO; VIANA, 2004). Factors such as the higher relation between leaf area and number of fruits per plant, along with larger development period of the fruit, allow bigger fruits (VAAST et al., 2006). Araújo et al. (2007) observed larger and heavier beans from forested coffee trees compared to the ones managed under full sun, thus resulting in larger volume of processed coffee. This characteristic is partially due to the lower abscission level of fruits on forested coffee trees, promoting a larger volume of harvested coffee (LIMA et al., 2007).

Coffee quality is directly related to the type of pre-harvesting preparation. Husked, depulped and mucilage removed coffee show superior

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features when compared to natural coffee, whereas, in the wet processing the mucilage, portion of the fruit that may favor the development of microbian fermentation, is removed (BORÉM et al., 2008. The objective of this work was to evaluate coffee quality aspects, grown under foresting and under full sun, processed by wet and dry ways, in Southern Bahia region.

2 MATERIALS AND METHODS

The study was performed in a property located in Barra do Choça – Bahia, at 992m altitude, (14°51'S e 40°37'O). The Catuaí Amarelo cultivar seedlings were planted in January 2001, spaced 4 x 1 m. In forested system treatments, grevillea (*Grevillea robusta* A. Cunn.) plants were used, implanted in January 2001, spaced 16 x 8 m. The coffee fruits collection, in both harvesting processes, was performed by means of manual selective harvest, picking from the plant only the cherry and dry fruits. At the end of the day, part of the harvested coffee volume was subjected to wet processing. Other part of the rim picked fruits, the form of cultivation was dry processed.

In dehusked coffee, mucilage was removed by fermentation. For coffee drying, an agricultural film greenhouse was used, located in UESB, in the Vitória da Conquista – BA campus. Coffee fruits were subjected to drying until total humidity for storage (11,5%) was achieved.

Humid mass (MU), dry mass (MS), humidity level (TU) and fruit yield (RF) evaluations were performed in samples constituted by 100 fruits at the time of harvesting, subjected to air circulation greenhouse at 60°C temperature for 48 hours, finding MS. As for MU and MS were determined the TU and RF, according to the formula TU = (MU-MS)/MS*100 and RF = MS/MU*100 respectively, with the results expressed in percentage. In post-drying were determined dry mass of the parcel (MSP) and processed coffee mass (MB).

The physical ratings were performed in the Coffee Rating Laboratory at the Cooperativa Mista Agropecuária Conquistense – COOPMAC, by a professional accredited by the Agriculture Ministry. In samples containing 300 grams of processed coffee, subjected to a sieve set, were selected the beans with medium diameter above 1,7 mm (17 UP), beans with diameter between 1,6 and 1,3 mm (13 / 16), beans with diameter above 1 mm, selected the empty locule beans 10 (MC), beans with diameter inferior to 1 mm were rated as bored and empty (BC). In the fractions retained in every sieve the coffee percentage was determined and the defects were separated, quantifying the number of defects (DEF) (BRASIL, 2003).

Features related to the coffee chemical composition were performed at the Coffee Quality Laboratory at the Minas Gerais Agricultural Research Company (Laboratório de Qualidade do Café na Empresa Pesquisa Agropecuária de Minas Gerais – EPAMIG) by means of the parameters: total titratable acidity (ATT), according to Carvalho et al. (1994); caffeine (CAF) according to Li, Berguer and Hartland (1990); Hydrogen potential (pH) assessment performed through a DIGIMED-DMPH-2 digital pH meter; reductor sugars (AR), non-reductor sugars (ANR), total sugars (AT) extracted by the Lane-Enyon method, quoted by the Association of Official Analytical Chemistry - AOAC (1990) and determined by the Somogy technique adapted by Nelson (1944); PPO enzyme activity (PFO) according to Carvalho et al. (1994) and electrical conductivity (CE) according to Loeffler, Tekrony and Egli (1988). The soluble solids parameters (SS), total chlorogenic acids (ACT) and total phenoic compounds (CFT) were determined according to AOAC (1990).

The random block lining was used, with the treatments arranged in factorial 2 x 2 scheme, with five repetitions, being the treatments formed by fruits harvested in *C. Arabica* crops, Catuaí Amarelo cultivar, forested and under full sun, and those fruits, in two processing ways (wet and dry). Each parcel was formed by 10 litres of cherry or depulped coffee, placed on wooden frames, with useful area of 1 m². the data obtained were subjected to homogeneity and normality tests, followed by variance analysis and F test at 5% probability, through software SAEG, version 9.1.

3 RESULTS AND DISCUSSION

Higher MU and MS values were observed in dry processed coffees when compared to the wet processed, under forested or full sun systems (Table 1). Exocarp and mucilage removal, present in the coffee fruits, contributed in an effective way to such behavior. Saraiva et al. (2010) observed that the wet way reduced the coffee mas to be dried, lowered the coffee volume to be stored and processed, and also reduced the risks of undesired fermentation in drying.

TABLE 1 - Humid mass (MU) and dry mass (MS) in coffee fruits from forested and under full sun systems, subjected to post-harvesting management, wet and dry ways.

MU	Dry way	Wet way	Average
Forested	135,22 A a*	72,96 B a	104,09
Full sun	120,82 A b	68,05 B b	094,43
Average	128,02	70,50	-
CV = 1,44%			
MS	Dry way	Wet way	Average
Forested	47,80 A a*	33,53 B a	40,66
Full sun	44,12 A b	32,13 B b	38,12
Average	45,96	32,83	-
CV = 1,60 %			

*Distinct lower letters indicate difference in post-harvest management, averages with distinct lower letters indicate differences in harvest system, by the T test, at 5% probability.

MU and MS of forested coffee trees were higher when compared to full sun trees, although the amplitude of values was inferior to the one verified when the distinction between ways was performed. Araújo et al. (2007) verified higher volume and weight of the cherry fruits from coffee trees forested with grevillea, when compared to the ones conducted under full sun. The authors attribute such feature to factors such as the greater relation between leaf area and number of fruits and to the larger fruit formation period with the mother-plant. Thus becomes evident the contribution of arboreous component for the formation of larger mass fruits, which could benefit the coffee producer.

It should be emphasized that the reduction after the drying operation gives a decrease in dry mass by removing some considerable humidity in the fruit as observed by (BROOKER; BAKKER-ARKEMA; HALL, 1992) leading to the reduction of agricultural beans' mass with the decrease of humidity level.

For RF were observed higher values for coffees grown under full sun, when compared to forested crops (Figure 1A). Such condition is due to the fact that forested coffees show higher amounts of husk and mucilage, as observed by Pezzopane et al. (2007) in coffee of the cultivar IAC 4045 grown under full sun and consorted with "Prata-Anã" banana tree.

RF of dry processed coffee was higher than the observed in dry way (Figura 1 B). Such effect is due to the removal of low density fruit components such as mucilage and exocarp, during post-harvest management. Mucilage may vary between 20 and 25% of cherry fruits' humid basis and between 0,5 and 2 mm in thickness, depending on the variety, maturation stage and environmental crop conditions (ELIAS, 1978).

For TU higher values were observed in fruits from forested trees, when compared to fruits grown under full sun (Figure 1 C). such fact could be related to the presence of the arboreous component in the formation of a microweather with easy temperatures and lower incidence of winds, which contributes to the conservation of humidity present in this form of cultivation (MATSUMOTO; VIANA, 2004).

According to the results shown in figure 1D, dry processed coffee fruits show lower humidity (64%) when compared to wet processed coffee fruits (53%). According to Silva et al. (2006), dry processed cherry fruits present humidity levels of 71,8 %, while for dry processing the same authors found fruits with humidity level of 45%. Thus, dry processed fruits show higher humidity since they contain in the exocarp a considerable part of the humidity present in mucilage. The removal of mucilage and exocarp (depulping) in wet processing contributes for the reduction of fruits' humidity.

In this study yield indexes between 52,15% and 77,94% were verified for the analyzed coffees. According to Gaspari-Pezzopane, Medina Filho and Bordignon (2004), in studies with *C. arabica*, Catuaí cultivar, conducted under full sun and dry processed, similar indexes were verified to those observed in the present study (55,3%).

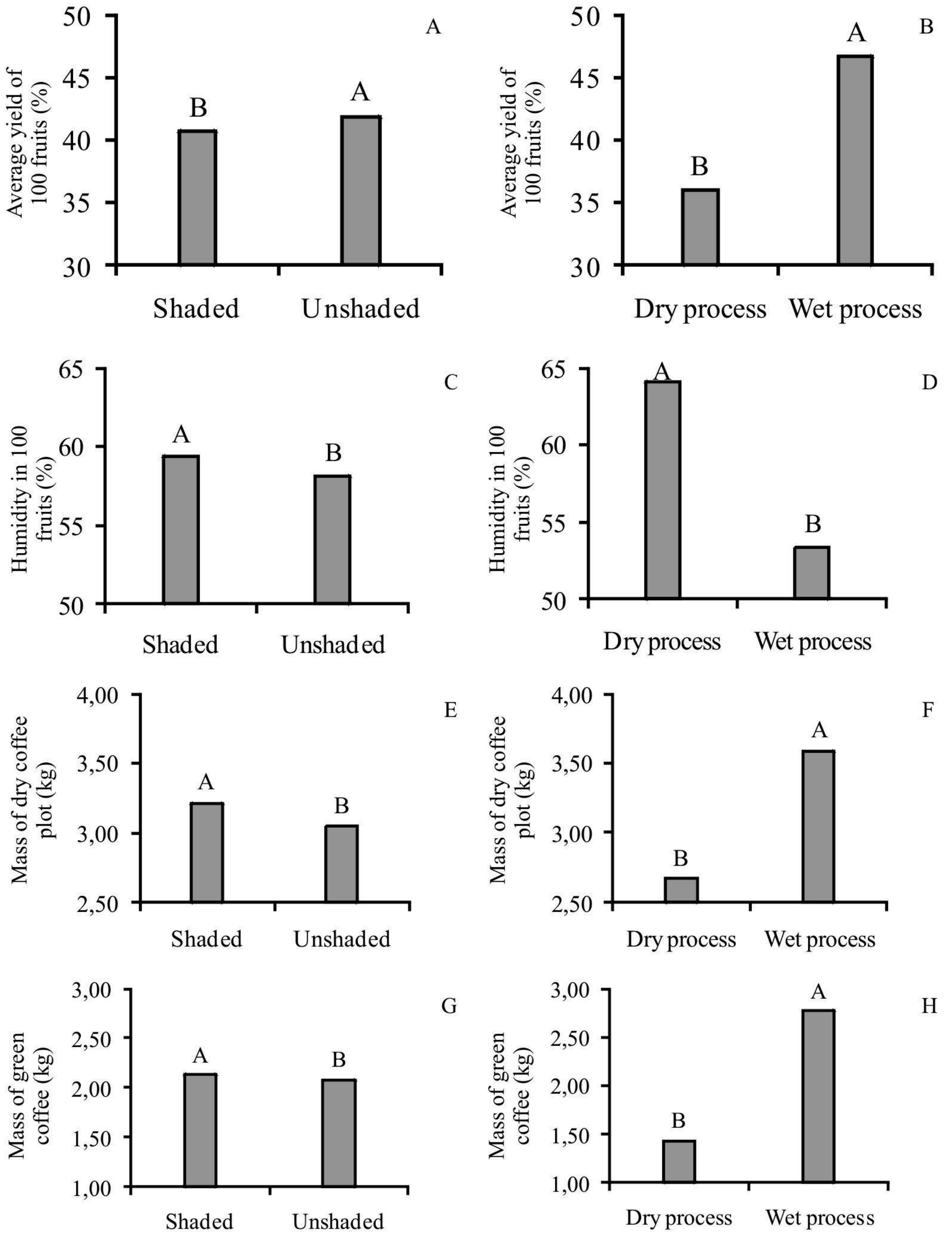

FIGURE 1 - Average yield and humidity levels in 100 fruits and processed coffee mass in 10 litres of *C. Arabica*, from forested and under full sun systems, subjected to dry and wet post-harvesting.

For coffees from crops conducted by forested and full sun systems, lower RP levels were verified when those were subjected to dry processing (Table 2). Such results are due to the presence of mucilage and exocarp in the fruit. Such components show low specific weight which contributes to the reduction of coffee mass and, consequently, favors the reduction of RP.

When wet processed coffee yield was observed, as cultivation systems are concerned, higher yield values were verified for the full sun system (77,94%) (Table 2). The results differ from the ones found by Muschler (2001), who evaluated quality increase in under-optimal regions for coffee in Costa Rica. Muschler (2001) observed that coffees from full sun and forested systems, with different leves of *Erythrina poeppigiana* (Walp.) O. F. Cook, under wet management, showed yield varying from 81,4% to 83,4% respectively but not significant. In the present study, in the different post-harvest management forms, when the contrast between conductions was analyzed, were verified higher RP levels in full sun systems. Such values confirm Pezzopane et al. (2007).

Pezzopane et al. (2007) found higher yield values for the full sun system (44,6%), when compared to the crops consorted with "Prata-Anã" banana trees (42,9%). Lower yield in forested coffee could be related to the higher volume of husk and mucilage, when compared to coffee tree conducted under full sun.

For the dry coffee mass of the parcel (MSP), in a similar way to the observed for the 100 fruits' samples, higher values were observed in fruits from forested areas (Figura 1 E). Such information could be applied to later studies in which there is the need to manipulate smaller samples, indicating the possibility to use smaller parcels, without harm related to the quantitative assessment of fruits' dry mass. Geromel et al. (2008) verified that, although the fruits' size in forested trees (*Coffea arábica* L. cv. IAPAR 59) was superior to the ones from full sun system, there were no differences when the mass of the fruits was evaluated. Higher fruit volume under shading was attributed to higher development of perisperm. However, Muschler et al. (2001) did not verify differences in the size of fruits for semi shaded coffee trees with shading levels varying from 40% to 80% in field conditions.

Lower MSP was verified for coffees from dry processing (coconut coffee) when compared to the wet processing, since they show fruits with mucilage and exocarp, components of low specific weight which contribute for coffee's mass reduction (Figure 1 F).

MB from forested management was higher when compared to full sun managed fruits (Figura 1 G). Forested coffees have a tendency to present higher mass since their fruits remain longer connected to the plant, providing higher number of photoassimilates (VAAST et al., 2006).

Araújo et al. (2007) encountered bigger size and weight in fruits from forested tree when compared to the ones conducted under full sun, resulting in higher volume of processed coffee.. Araújo et al. (2007) attributed such feature to the bigger relation between leaf area and bigger fruit development period, allowing higher quality.

When the mass of processed coffee, dry and wet processed, is compared, a difference was found between the treatments (Figure 1 H). Wet processed coffee presented larger mass when compared to dry processed coffee. Such behavior is due to the removal of part of the empty locule or malformed coffee during the wash of such fruits. In the moment of coffee washing the higher density fruits are separated in the washer, and those fruits are used in wet processing (BORÉM et al., 2008). Therefore, wet processed coffees present larger mass than those dry processed.

TABLE 2 - Parcel yield (RP) with *C. arabica* from forested and full sun systems, subjected to dry and wet post-harvest management.

RP	Dry	Wet	Average
Forested	52,15 B b*	76,92 A b	54,53
Full sun	55,24 B a	77,94 A a	66,59
Average	53,69	77,43	-

CV = 1,07%

*Distinct lower letters indicate difference in post-harvest management, averages with distinct lower letters indicate differences in harvest system, by the T test, at 5% probability.

Since they present larger mass, wet processing leads to the formation of lots with lower diameter beans (screen), which contributes for the larger presence of chemical compounds (soluble solids, sugars and acids), favoring the formation of beverages of superior quality as observed by Farah et al. (2006), in a correlation study between cup teste and chemical attributes found in processed coffees in Brazil.

In studies performed in Mexico by Lin (2009), about different shading levels in Bourbon cultivar coffee, it was observed that sun radiation, temperature and soil humidity interferred in fruits' growth, being such factors strongly controlled by the presence of arboreous component, in size. For the fruits' weight a high correlation with soil humidity was observed.

As for screen classification (Figure 2A), in general, it was observed that the use of arboreous component in coffee harvests contributes for the increase of production quality, since a high percentage of bigger beans was verified (17UP) and reduction of depreciation elements of bored and empty beans (BC) (Figure 2 A). Smaller percentage of BC beans were encountered in fruits from forested system, when compared to coffees grown under full sun (Figure 2 C). The high concentration of beans classified as 17UP from forested management leads to higher later homogeneity in roasting operations as observed by Salla (2009).

According to Geromel et al. (2008), coffee fruits developed in shading conditions are bigger than those brought up under full sun. However, in the present study, such behavior was verified only for the 17UP class, with no difference being observed for 13/16 and MC (Figure 2 A). Ricci, Menezes and Costa (2006) verified that 71,1% of the assessed fruits under shaded system were retained in the 17UP screen. Opposing the previous considerations, in study performed by Muscheler (2001), the condition of different periods of artificial shading, in productive coffee branches, did not alter the classification of the beans when compared to plants grown under full sun.

With a broader vision, Bosselman et al. (2009) reported that shading can increase the fruit's size as long as optimal temperature and lighting levels are conditioned. For Muscheler (2001), studying the Catimor variety, the increase of shading levels provided a concentration of coffees clasified as 17 UP. The presence of trees in the crops promotes a reduction in temperature resulting in longer maturation periods and the conditioning of a larger flow of carbohydrates for each fruit formed, respectively (VAAST et al., 2006).

The availability of photoassimilates was related to the effects of shading in restricting the formation of floral buds and elevate plant's total leaf area, resulting in an increase of the relation of leaf area per fruit (VAAST et al., 2006). The more intense biannuality in crops under full sun can be another factor that interferes in the larger quantity of empty beans in this system, for low production years.

When assessed the post-harvest treatment, was verified that the wet management showed larger percentage of beans retained in 17UP screen (Figure 2 B). it must be highlighted that in post-harvest management of coffees grown at Planalto da Conquista, the fruits washing, until then, was a stage used only in wet processing. Due to the immersion of the fruits in water, most of the empty locule of malformed (lower density) beans tends to occupy the superficial portions of the washer. Therefore, such fruits are easily separated and thrown away, raising the percentage of bigger sizer fruits in another portion, which are wet processed. The dry processed coffee, since it is not washed, was put to dry in a full form, without separating the empty locule beans in washing, therefore showing a lower percentage of coffee retained in screen 17 UP.

When the post-harvest treatment was evaluated, it was verified that the wet management showed smaller percentage of bored and empty beans (Figure 2 D). the removal of empty beans from the surfacing portion is not completely performed in the washing operation due to the sedimentation of those due to their high level of humidity, making them heavier. According to Illy et al. (1982), the cellular disorganization observed in coffees classified as defective raises their water absorption capacity as the cellular damage level rises. Malta, Pereira and Chagas (2005) alert for the negative effect of the presence of defects in the qualitative analysis interpretation of coffee beverages.

In dry post-harvesting processing, the fully dried coffee showed larger percentage of bored and empty beans (Figure 2 D). in the region of Barra do Choça, the fruits are picked and shook up in the field, and the washing is not performed in the moment of coffee processing, thus composing the coffee classified as "choice". In the present study, the contribution of "choice" coffee was not observed.

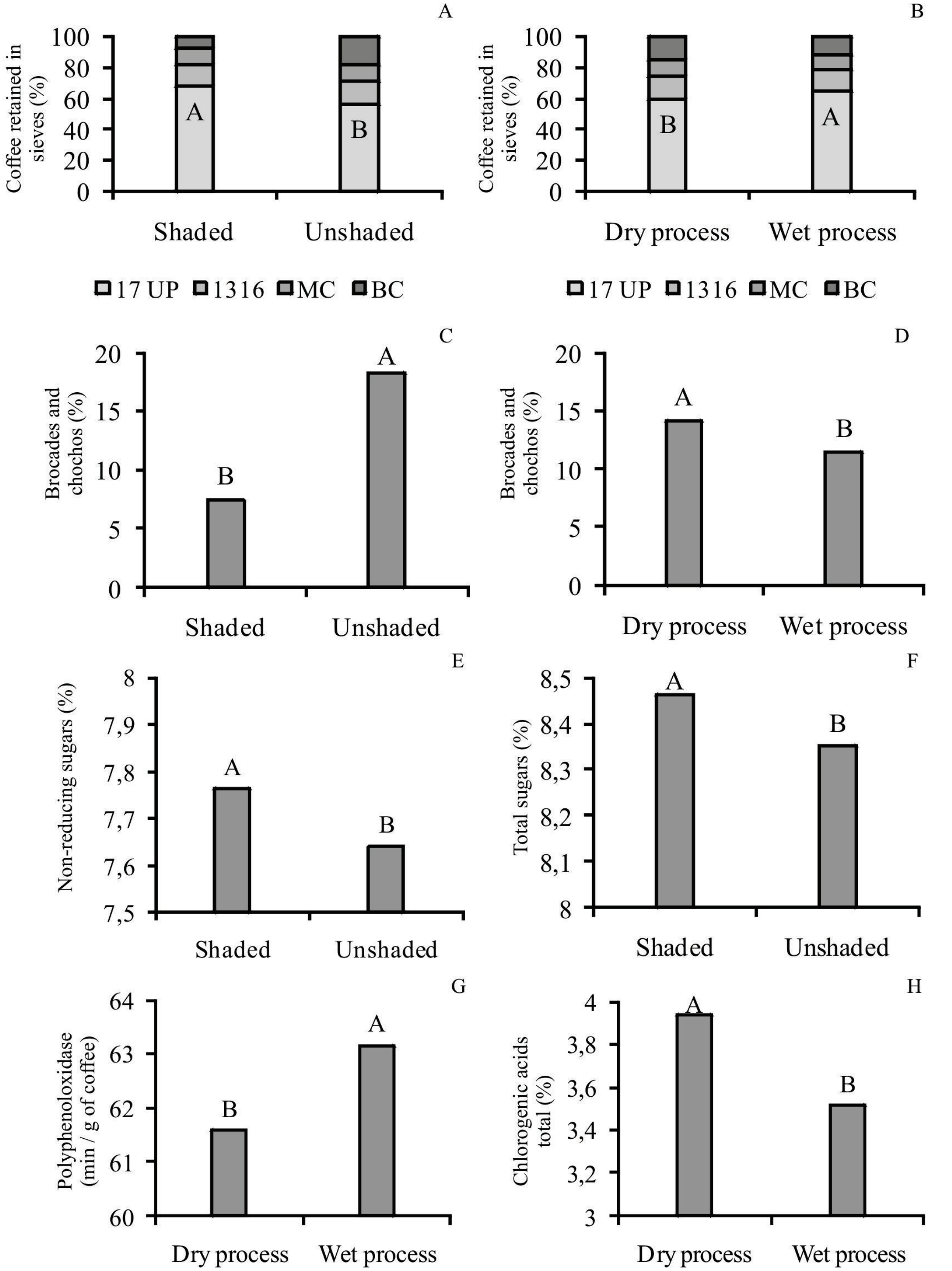

FIGURE 2 - Screens, bored and empty coffees, non reductor sugars, total sugars, total PPO and chlorogenic acids in *C. arabica* from forested and full sun systems, subjected to dry and wet post-harvest managements.

Knop, Bytof and Selmar (2006) did not verify post-harvest management effects for the saccharose levels. However, opposing to the present study, a reduction was observed in the levels of fructose and glucose. For wet processed coffees an increase was detected in ANR and AT, for coffees from forested areas (Figure 2 E and 2 F). Similar behavior was verified before by Guyot et al. (1996). The referred authors verified in Cuilapa, Guatemala, a 4% increase of ANR in shaded fruits when compared to full sun crops.

Geromel et al. (2008) verified higher values for the relation between reductor and non reductor sugars in forested coffees. With larger availability of substrates, fungal and bacterial activities rise, resulting in acidity present in forested coffees. According to Jackelers and Jackels (2005), in general, the transition between the formation and maturation stages of the coffee fruit is followed by an interruption in the amount of carbohydrates and of a reduction in the realtion between reductor and non reductor sugars (AR/ANR) in the perisperm of the coffee seed. According to Geromel et al. (2008) the larger the bean, under shading condition, larger the relation between AR/ANR.

Geromel et al. (2006) described that the saccharose synthesis enzyme plays an important part in the accumulation of ANR in the last stages of development of the pericarp and endosperm tissues in coffee fruits. In later study, Geromel et al. (2008) verified that, in shading conditions, there was a ANR decrease in the last stages of fruit developmen and the AR elevation was maintained when compared to the full sun crop condition. Despite the described alterations, in a similar way to the present study, the ANR concentration in shaded coffees kept superior to the full sun coffees.

Joet et al. (2010), analysing the influence of environmental factors in the wet process and the biochemical interactions of the coffee compounds, observed that air temperature, during the development of coffee fruits, can influence the routes of many compounds, among them, sugars and chlorogenic acids. Higher PPO activity was verified in wet processed coffee fruits (Figure 2 G). when the fruits were subjected to wet management, the removal of husk and mucilage from the fruits reduced the processes of microbiological injury by means of fermentation.

Despite the wet management processes promote a certain level of mechanic injury to the fruits, the reduction of factors related to microbiological injuries had larger impact in PPO activity. Santos, Chalfoun e Pimenta (1998), in studies with wet processing and types of coffee drying over the chemical composition verified that husked cherry coffee, dried on the ground, showed higher PPO enzyme activity, when compared to coffees dried in dryer. The authors suggest that the vulnerability of the integrity of the cellular membrane of the fruits, when this coffee is de-husked and transferred to the dryer with temperatures of 60ºC, may alter the chemical compounds and PPO reduction.

For Koshiro et al. (2007), the chlorogenic acids are the main secondary metabolytes found in coffee fruits. Avelino et al. (2005) state that the ACT level is directly related to the macroweather of the crop regions, mostly to the thermic variations. Among the mais factors that alter the thermic amplitude of farm locations, the altitude was considered as the most impact factor when compared to shading. Vaast et al. (2006) observed higher ACT levels for shaded coffees. In the present study no effect was verified of the incident light regime for ACT. Similar behavior was verified by Geromel et al. (2008).

In the present study, dry processed coffees presented higher ACT levels (Figure 2 H), characterizing post-harvest management effect. In a similar way, Balylaya and Clifford (1995) verified the occurrence of higher ACT levels for *C. arabica* subjected to dry processing. However, for the fruits of *Coffea arabica* L. from the Bourbon amarelo, Catuaí vermelho and Rubi cultivars, Duarte, Pereira and Farah (2010) did not observe differences between wet and semi-dry processings. According to the same author, for hibrids and *C. robusta* the ACT levels subjected to wet processing were superior to the ones subjected to semi-dry processing. Murthy and Manonmani (2009) observed lower ACT levels for *C. arabica* when compared to *C. robusta*.

Farah et al. (2006), evaluating the correlation between cup test and chemical attributes of brazilian coffee, observed higher ACT levels for inferior quality coffees and lower values were associated to better quality coffees. Thus, in the present study, wet processed coffees tend to show superior quality.

ATT values found were considered elevated (Table 3). According to Borém et al. (2008) the cause of elevation of ATT levels is related to the degenerative effects in the fruits' membranes. Such injuries would be promoted by high temperatures in the drying environment, resulting in the liberation of organic acids.

TABLE 3 - Total titratable acidity (ATT) of C. arabica from forested and full sun systems subjected to dry and wet post-harvest management.

ATT	Dry	Wet	Average
Forested	219,00 A a*	202,00 B a	210,50
Full sun	207,00 A b	206,00 A a	206,50
Average	213,00	204,00	-

CV = 3,78%

*Ldistinct capital letters indicate difference in post-harvest management, averages with distinct lower letters indicate differences in crop system by the F test, at 5% probability.

In coffee crops managed under full sun no effect was verified in the post-harvest management (Table 3). For the forested crops, higher values of ATT were observed for the dry processing. However, Jackelers and Jackels (2005) observed that, in the wet process there was high acidity increase due to the alteration of the carbohydrate matrix present in mucilage adhered to the endocarp of the fruit, as fermentation result.

Since, in the present experiment, the revolving of wet and dry processed coffees was performed in the same intensity, the larger presence of sugars in forested and dry processed coffees favored a larger dissemination of pathogens. The search for natural cherry coffee with lower acidity can be obtained by a faster drying, with more revolving of the fruits' mass. In dry processed fruits, the presence of foresting raised the ATT levels when compared to full sun. however, for the wet processing no foresting effect was observed in relation to the absence of the same (Table 3).

4 CONCLUSIONS

The association of trees to coffee crops contributes to improve the physicochemical aspects of the beans. The use of wet process post-harvest management improves the physical quality of coffee.

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