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MODIFICATION IN THE SENSORY PROFILE OF COFFEE THROUGH ANAEROBIC FERMENTATION TECHNIQUES IN PROCESSING METHODS

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ABSTRACT - One technique that has been drawing the attention of producers is the induced fermentation of the fruits. In the induced fermentation process, the fermentation speed is increased, but environmental interferences with different microbiota can alter the fermentation process, making it difficult to repeat the results. The objective was to induce anaerobic fermentations in coffee fruits, through different processes, aiming at modifying the sensory profile of the beverage. The experiment was conducted in 2019, with 'Mundo Novo IAC-379/19' coffee fruits, which came from full harvest, with 70% of fruits in the parchment stage. On the day of harvest, the coffee was separated into 78 experimental plots, each containing 10 L. The treatments used were: addition extract of *Citrus reticulata*, *Carica papaya*, *Ananas comosus*, *Eucalyptus* spp. leaf and addition of sugar, at concentration of 10% in aqueous solution (stored in 12 L buckets) and treatment with water only. 24 and 48h fermentation periods were tested, besides two processing methods, natural and with peeled fruits. In addition, the fruits were tested without induced fermentation for natural and peeled coffee. It is concluded that the treatment with fermentation induced for 24 h without the addition of extracts in wet processing yielded coffees of better sensory quality, with a final score of 85.33. The wet processing of coffee fruits without the addition of extracts, immersed in water for 24 h, yielded better sensory quality. The addition of *Ananas comosus* extracts implies a reduction in the sensory quality of coffee in the induced fermentation process.
Keywords: special coffees, induced fermentation, post-harvest, quality.

MODIFICAÇÃO DO PERFIL SENSORIAL DO CAFÉ POR MEIO DE TÉCNICAS DE FERMENTAÇÃO ANAERÓBICAS EM MÉTODOS DE PROCESSAMENTO

RESUMO - Uma técnica que vem chamando a atenção dos produtores é a fermentação induzida dos frutos. No processo de fermentação induzida, a velocidade de fermentação é aumentada, porém as interferências ambientais com diferentes microbiotas podem alterar o processo fermentativo, dificultando a repetibilidade dos resultados. Objetivou-se induzir fermentações anaeróbicas nos frutos de café, por meio de diferentes processamentos, visando a modificação no perfil sensorial da bebida. O experimento foi conduzido no ano de 2019 com frutos da cultivar Mundo-Novo IAC-379/19, com 70 % de frutos no estádio de maturação cereja. No dia da colheita, separou-se o café em 78 parcelas experimentais, com 10 L cada. Os tratamentos utilizados foram adição de extratos de: *Citrus reticulata*, *Carica papaya*, *Ananas comosus*, folhas de *Eucalyptus* spp. e adição de açúcar, na concentração de 10% em solução aquosa (em baldes com 12 L) e um tratamento somente água. Foram testados tempos de 24 h e 48 h de fermentação e dois processamentos, natural e via úmida. Adicionalmente, testou-se os frutos sem fermentação induzida para o café natural e para o descascado. Conclui-se que o tratamento com fermentação induzida por 24 h sem a adição de extratos em processamento via úmida propiciou cafés de melhor qualidade sensorial, com 85,33 pontos de nota final. O processamento via úmida, com fermentação induzida por 24 horas sem a adição de extratos, propiciou cafés de melhor qualidade sensorial. A adição de extratos de *A. comosus* implica em redução da qualidade sensorial na bebida do café em processo de fermentação induzida.
Palavras-chave: cafés especiais, fermentação induzida, pós-colheita, qualidade.

INTRODUCTION

The coffee agribusiness is of great importance in the Brazilian economy, and it is responsible for the generation of income and jobs (CAIXETA et al., 2008). According to Conab (2020), the Brazilian production for 2020 was 61,6 million (60 kg-processed bags). In addition to productivity, the sensory quality of coffee is also very important for the coffee grower, and like productivity, quality is influenced by several factors.

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Genetic factors (choice of species and cultivar) are studied in order to identify promising materials for the production of specialty coffees (FASSIO et al., 2019; FERREIRA et al., 2012; PEREIRA et al., 2019a). In addition, it is known that post-harvest processing has a decisive influence on coffee quality, being able to alter its sensory attributes, as well as its nuances. Several studies allow the conclusion that dry and wet processing result in coffees with different sensory profiles, such as flavor, body and sweetness (MALTA et al., 2013; OLIVEIRA et al., 2013; TAVEIRA et al., 2015). The concept of coffee quality is closely linked to the quality of the beverage, and higher quality coffees are commonly characterized by their characteristic flavor, linked to a good body, natural acidity and which is pleasant to consumer taste (BORÉM, 2008).

Currently, the induced fermentation of coffee fruits appears as an alternative post-harvest technique with great emphasis on the production of specialty coffees. Fermentations are common in natural coffees (dry processing), that is, those processed with the presence of all fruit structures. However, in the induced fermentation process, the fermentation speed is increased, significantly interfering with the quality of the final product. However, the diversity of environments where induced fermentations occur can significantly interfere in the result of the fermentation process due to the diversity of the microbiota in each location, which makes the proposed treatments repeatable (SILVA, 2014). Microbiological activity, as well as fermentation time, can alter the concentration of some compounds, such as sugars and free amino acids, and consequently interfere with the Maillard reaction and volatile compounds during the roasting process (De MARIA et al., 1996).

Several studies with coffee fermentation have been conducted using microorganisms previously isolated from coffee crops (BRESSANI et al., 2018; EVANGELISTA et al., 2014; EVANGELISTA et al., 2015). However, some experiences are reported by coffee growers, but in an empirical way, demanding scientific studies that can test such reports. Thus, aerobic and anaerobic induced fermentations are tested by coffee farmers in an impirical way, as well as with or without the addition of exogenous products, such as fruit extracts, honey, sugar, yeast, among other components.

Thus, due to the small amount of research studying fermentative processes induced in coffee, the objective was to evaluate the influence of induced anaerobic fermentation in different post-harvest processing methods, on coffee quality as a way to test some experiences reported by coffee growers.

MATERIAL AND METHODS

The experiment was conducted in 2019, in the Coffee Growing Sector of the Department of Agriculture (DAG), of Universidade Federal de Lavras (UFLA). To conduct this study, 'Mundo Novo IAC 379/19' coffee fruits were used, which came from full harvest, with 70% ripe fruits. On the day of harvest, the coffee was subjected to 26 different treatments, in a randomized block design (RBD), with three replications, totaling 78 experimental plots, consisting of 10L of coffee in each plot (Table 1).

The treatments used were: 1) addition of *Citrus reticulata* extract, 2) addition of *Carica papaya* extract, 3) addition of *Ananas comosus* extract, 4) addition of *Eucalyptus* spp. leaf extract and 5) addition of sugar, at a concentration of 10% (in 12 L buckets), with water, in addition to 6) a treatment with water only. The extracts were previously prepared by the work team on the day the experiment was set up. Fermentation times of 24 and 48 h of immersion in water were evaluated, as well as two post-harvest processing methods, with natural (dry) (N) and peeled fruits (wet) (P). Peeling was performed using a mechanical peeler (DMMP-04, Pinhalense). In addition, the fruits were tested without induced fermentation for natural coffee and peeled coffee, that is, processed in a conventional manner.

After the fermentation time in each treatment, the samples were dried on individual screens on a concrete terrain, until they reached 11.5% water content. As a drying protocol, "grain-by-grain" drying was established, with a density of 12 L coffee per square meter, during the first two days. Subsequently, layer folds were made day by day, until they reached the "dry half" stage, with 8 days of drying (BORÉM, 2008). Finally, after this stage, there were no more layer folds (Figure 1).

From the third day of drying, the coffee samples were constantly turned (10-15 daily turns). After drying, the samples remained in storage for 30 days, in fine mesh plastic nets, suitable for fruit storage, in storage bins, at room temperature, without exposure to moisture and sunlight, to standardize the water content in grains. After this period, the samples were processed and sensory analysis was performed by three certified "Q-graders" panelists, using the protocol proposed by the Specialty Coffee Association/SCA (LINGLE, 2011). The evaluated sensory attributes were: uniformity, clean cup, sweetness, fragrance, flavor, acidity, body, finish, balance, general and final score (sum of all attributes).

Using the Sisvar® software (Ferreira, 2011), the significance of the treatments was verified using the F test and, for the characteristics that had a significant difference, the means were grouped by the Scott-Knott test at 5% probability. The multivariate analysis of principal components was also performed using the Genes software (CRUZ, 2006). The analysis of canonical variables was performed to evaluate the similarity of the treatments, through graphic dispersion, and the multivariate analysis of variance (ANOVA) was performed.

TABLE 1 - Description of the treatments used as anaerobic fermentation techniques in coffee fruits.

No.	Extract used	Fermentation time	Processing
1	*Ananas comosus*	24 h	Peeled
2	*Ananas comosus*	24 h	Natural
3	*Ananas comosus*	48 h	Peeled
4	*Ananas comosus*	48 h	Natural
5	Sugar	24 h	Peeled
6	Sugar	24 h	Natural
7	Sugar	48 h	Peeled
8	Sugar	48 h	Natural
9	*Eucalyptus* spp.	24 h	Peeled
10	*Eucalyptus* spp.	24 h	Natural
11	*Eucalyptus* spp.	48 h	Peeled
12	*Eucalyptus* spp.	48 h	Natural
13	*Carica papaya*	24 h	Peeled
14	*Carica papaya*	24 h	Natural
15	*Carica papaya*	48 h	Peeled
16	*Carica papaya*	48 h	Natural
17	*Citrus reticulata*	24 h	Peeled
18	*Citrus reticulata*	24 h	Natural
19	*Citrus reticulata*	48 h	Peeled
20	*Citrus reticulata*	48 h	Natural
21	No fermentation	No fermentation	Peeled
22	No fermentation	No fermentation	Natural
23	Only water	24 h	Peeled
24	Only water	24 h	Natural
25	Only water	48 h	Peeled
26	Only water	48 h	Natural

FIGURE 1 - Processing and drying of coffee fruits submitted to different treatments. Subtitle: A - Addition of extracts; B and C - Containers after addition; D - Containers during fermentation; E and F - drying of the samples. Source: The authors (2019).

RESULTS AND DISCUSSION

Through the observed results, there was a significant difference for the sensory attributes: fragrance/aroma, flavor, acidity, body, finish, balance, overall and final score (sum of all attributes). When the coffee samples of the different treatments were evaluated for uniformity, clean cup and sweetness, no significant differences were found. For the attributes fragrance/aroma, flavor and finish, three distinct groups were formed. For balance and overall, 2 distinct groups were formed and, for the characteristics of acidity, body and final total score, four distinct groups were formed among the treatments (Table 2).

TABLE 2 - Average sensory attributes fragrance/aroma, flavor, acidity, body, finish, balance, overall and final score, as a function of different fermentation times, processing types and exogenous components applied in the anaerobic fermentation of coffee fruits.

Nº	Treatments	Frag/Aroma	Flavor	Acidity	Body	Finish	Balance	Overall	Final
1	*Ananas comosus* 24 P	7.00 c*	7.00 c	7.00 d	7.00 d	7.00 c	7.00 b	7.00 b	79.00 d
2	*Ananas comosus* 24 N	7.50 b	7.83 a	7.50 c	7.67 b	8.00 a	7.50 a	7.50 a	83.50 c
3	*Ananas comosus* 48 P	7.50 b	7.50 b	7.50 c	7.50 c	8.00 a	7.50 a	7.50 a	83.00 c
4	*Ananas comosus* 48 N	7.50 b	7.67 b	7.50 c	7.50 c	7.50 b	7.33 a	7.50 a	82.50 c
5	Sugar 24 P	7.83 a	8.00 a	7.50 c	8.00 a	8.00 a	7.50 a	7.50 a	84.17 b
6	Sugar 24 N	7.83 a	8.00 a	7.50 c	7.50 c	7.83 a	7.33 a	7.50 a	83.50 c
7	Sugar 48 P	7.67 a	7.83 a	7.50 c	8.00 a	8.00 a	7.50 a	7.67 a	84.33 b
8	Sugar 48 N	7.83 a	8.00 a	7.50 c	8.00 a	8.00 a	7.50 a	7.50 a	84.33 b
9	*Eucalyptus* spp.24 P	7.50 b	7.83 a	7.50 c	7.50 c	8.00 a	7.50 a	7.50 a	83.33 c
10	*Eucalyptus* spp. 24 N	7.50 b	8.00 a	7.50 c	7.67 b	8.00 a	7.50 a	7.50 a	83.67 b
11	*Eucalyptus* spp. 48 P	7.50 b	7.50 b	7.50 c	7.50 c	7.67 b	7.50 a	7.33 a	82.50 c
12	*Eucalyptus* spp. 48 N	7.50 b	7.83 a	7.50 c	7.50 c	7.50 b	7.50 a	7.33 a	82.67 c
13	*Carica papaya* 24 P	7.50 b	7.67 b	7.50 c	7.50 c	8.00 a	7.50 a	7.50 a	83.67 b
14	*Carica papaya* 24 N	7.50 b	7.83 a	7.50 c	7.50 c	8.00 a	7.50 a	7.50 a	83.33 c
15	*Carica papaya* 48 P	7.50 b	7.83 a	7.50 c	8.00 a	7.50 b	7.50 a	7.50 a	82.83 c
16	*Carica papaya* 48 N	7.50 b	7.50 b	7.67 b	7.50 c	7.83 a	7.33 a	7.50 a	82.67 c
17	*Citrus reticulata* 24 P	7.50 b	7.67 b	7.50 c	7.50 c	7.50 b	7.50 a	7.50 a	82.67 c
18	*Citrus reticulata* 24 N	7.50 b	8.00 a	7.50 c	7.67 b	8.00 a	7.50 a	7.67 a	83.83 b
19	*Citrus reticulata* 48 P	7.50 b	7.67 b	7.50 c	7.67 b	7.50 b	7.50 a	7.50 a	82.83 c
20	*Citrus reticulata* 48 N	7.50 b	8.00 a	7.50 c	8.00 a	8.00 a	7.67 a	7.50 a	84.33 b
21	No fermentation P	7.50 b	7.83 a	7.50 c	7.5 c	8.00 a	7.50 a	7.50 a	83.33 c
22	No fermentation N	7.83 a	8.00 a	7.50 c	7.67 b	8.00 a	7.50 a	7.50 a	84.00 b
23	Only water 24 P	8.00 a	8.00 a	8.00 a	8.00 a	8.00 a	7.50 a	7.83 a	85.33 a
24	Only water 24 N	7.50 b	7.50 b	7.67 b	7.5 c	7.33 b	7.50 a	7.50 a	82.50 c
25	Only water 48 P	7.50 b	7.50 b	7.50 c	7.5 c	8.00 a	7.50 a	7.50 a	83.00 c
26	Only water 48 N	7.50 b	7.83 a	7.50 c	7.5 c	7.50 b	7.50 a	7.50 a	82.83 c

*Means followed by the same letter in the column, belong to the same group, according to the Scott-Knott grouping criterion at 5% probability, N = natural, P = peeled.

It was thus found that, for fragrance/aroma, there was superiority in the treatments with the addition of sugar, regardless of processing or fermentation time; without fermentation in dry processing (natural - N); and with only water with 24 h of fermentation in wet processing (peeled - P). With the addition of *Ananas comosus* 24 P extract, coffee samples showed a lower value for this variable. The other treatments were similar to each other, with intermediate values for the other groups. For acidity, the samples that received “only water 24 P” were superior to the other treatments. As with fragrance/aroma, also in the evaluation of acidity, coffee samples with the addition of *Ananas comosus* 24 extract were again the worst treatment.

As for the sensory attribute “body”, there was a superiority of some treatments compared to the others, namely, fermentation with addition of sugar 48 P, fermentation with addition of sugar 48 N, fermentation with addition of sugar 24 P; fermentation with addition of *Carica papaya* L. extract 48 P; fermentation with addition of *Citrus reticulata* extract 48 N; and fermentation with only water 24 P. Again, the coffee samples with fermentation with the addition of *Ananas comosus* 24 P extract was the worst in relation to this attribute.

For the sensory attributes flavor and finish, it was possible to form three distinct groups, according to the grouping methodology proposed with the statistical test. For both attributes, the coffee samples with *Ananas comosus* 24 D were the worst, being in the third group, inferior to the others. The coffee samples with treatments allocated in the upper clusters had different behaviors according to each sensory attribute. However, coffee samples with fermentation by adding the sugar extract stand out since, regardless of processing or fermentation time, they remained in the upper cluster for both sensory attributes.

For balance and overall, only two groups were formed, one consisting of coffee samples with *Ananas comosus* 24 D, which were the worst, and the other group comprising the coffee samples with all other treatments. Finally, for the final score, there was a superiority of coffee samples fermented with only water 24 D, with a score of 85.33, according to the SCA tasting protocol. Also according to the final score, coffee samples fermented with *Ananas comosus* 24 D were those that had the lowest final sensory score, that is, 79 points.

Above all, it is noteworthy that the coffee samples that received the standard coffee drying treatment, that is, dried naturally, or also which is dried without the presence of the fruit exocarp (peeled), presented characteristics such as medium acidity, high mean sweetness, caramel, milk chocolate and chestnut. On the other hand, the sensory profile linked to the coffee beverage of the samples with the best treatment, that is, those that were under fermentation for 24 h with only water, showed notes of milk chocolate, fruity, papaya, brown sugar, yellow fruits, high acidity and high sweetness. When the fruits were subjected to fermentation with *Ananas comosus* extract, for 24 h (worst treatment), the coffee beverage presented notes of acetic acid, and characteristics such as rough body and imbalance.

Through principal component analysis, which resulted in the scatter plot (Figure 2), the grouping of the twenty-six treatments was observed, resulting from the canonical analysis. It can be seen that the sensory attributes that most explain the results are taste and final score and, therefore, only these were used in the scatter plot.

It can also be observed that, in the lower left quadrant, treatment number 1 (fermentation with *Ananas comosus* for 24 hours, peeled) was grouped away from the main positive characteristics through sensory analysis, flavor and final score. Reverse to treatment number 1, in the lower right quadrante, some treatments were grouped next to the most important characteristic in sensory analysis, which is the final score, being they 20 (fermentation with *Citrus reticulata* for 48 h, natural processing), 22 (without fermentation, natural processing), 18 (fermentation with *Citrus reticulata* for 24 h, natural processing), 10 (fermentation with *Eucalyptus* spp. leaves for 24 h, natural processing), 6 (fermentation with sugar for 24 h, natural processing), and all these treatments are with 24 h of fermentation, except treatment 20 (48 h, with natural processing). Grouping was also observed in treatment 23 (fermentation with only water for 24 h, peeled), close to the final score, and this treatment was the one that yielded the highest score among all the others (Figure 2).

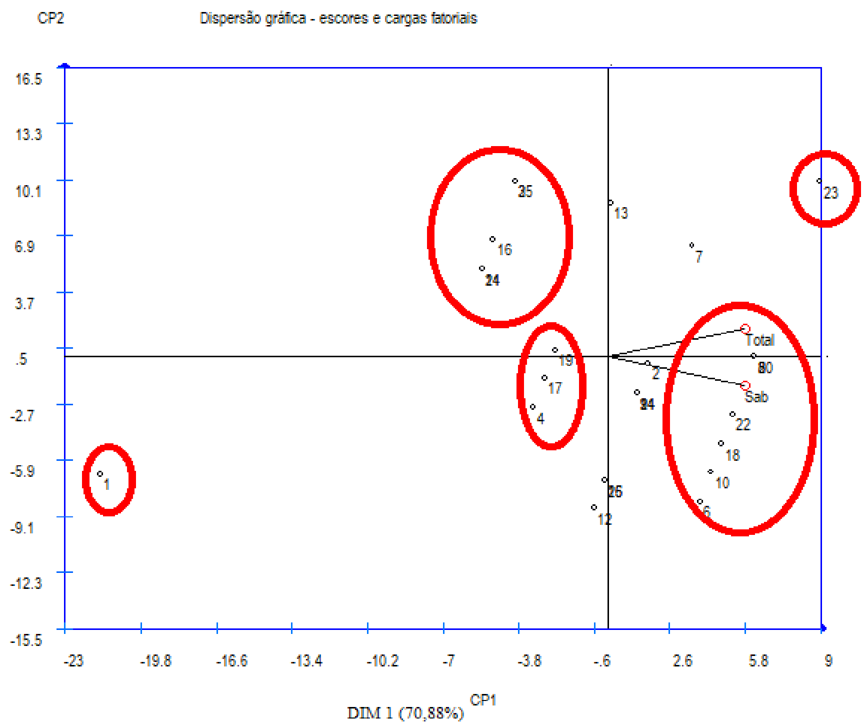

FIGURE 2 - Graphic dispersion of the treatments used as a function of different induced fermentation techniques in relation to the first (canonical variable 1) and the second (canonical variable 2), based on coffee flavor and final score. Caption: Numbers referring to treatments, as described in the methodology (Table 1). Source: The authors (2019).

According to Evangelista et al. (2014), the use of yeast from the coffee plantations, after isolation, implies changes in the sensory profile of coffee fruits, producing a caramel and fruity flavor. Allied to this, Ribeiro et al. (2017) report that sensory changes through induced fermentations are also influenced by the studied coffee cultivar, with variations in the result, as a function of choice. Bressani et al. (2018) also worked with yeast-induced fermentation, and found changes in the sensory profile, with noticeable improvement, thus implying the appearance of sensory notes of banana and cashew in coffee fruits, making it exotic.

It is noteworthy that, when in conditions to improve the sensory quality of coffee, this probably occurs due to the change in the concentration of compounds such as sugars that can contribute to the Maillard reaction, as well as volatile compounds during the roasting process (De MARIA et al., 1996). On the other hand, when under a deterioration condition of the sensory quality, the fact is possibly related to the production of acetic acid and also other compounds, resulting in unpleasant flavors on the palate, such as moldy, dirt and undesirable fermentation, or also due to the presence of microorganisms such as *A.* section *nigri* (IAMANAKA et al., 2014a; IAMANAKA et al., 2014b). Still, it is emphasized that some factors such as water pH, temperature, and the content of soluble solids can be used as indicatives to obtain greater precision and stability in the induced fermentation process (JACKELS; JACKELS, 2005; RODRIGUEZ-ZUNIGA et al., 2011).

It is known that the variation of the microbiota present in the drying environment of the coffee fruit interferes with its sensory attributes (De BRUYN et al., 2017). This way, it can be associated with chemical alteration and also in the constitution of the components of the grain (PEREIRA et al., 2020). Melo Pereira et al. (2015) report that the microbial growth during the fermentation can confer additional flavor notes due to the metabolites produced in this process, in view of the subsequent potential for migration of these compounds to the grain. These same authors also found that the perception of exotic notes from fermentation processes may be associated with specific compounds detected in this process, suggesting an important role for the microbiota in the development of these flavors. Gonzalez-Arenzana et al. (2020) found that in similar processes for wine culture, where there is induced fermentation, there was a positive variation in the sensory profile, and also that the fermentation time is variable according to the daily temperatures in the same period.

It was found that there was a marked improvement in the sensory quality of coffee beans, with fermentation for 24 h, in the peeled processing, but without the addition of exogenous components, that is, the microbiota that implied in the fermentative processes was implicit in the coffee crop, where the fruits originated. In this context, it is highlighted that this procedure is similar to the standard used as a way of pulping the coffee fruits. However, in this case study, it is noted that it can also be a method to be considered for decision making focused on production of coffees with a better sensory profile. Pereira et al. (2014) also observed that the microbiota existing in the coffee plantation implied improvements in the coffee sensory profile, when under accelerated fermentation processes, resulting in sensory profiles characterized by fruity, buttery and fermented nuances.

Pereira et al. (2019b) report that, during the evaluation of different processing methods and fermentative processes in coffee fruits, dry fermentation, that is, without immersion in water, was the one that resulted in the best sensory profile. However, these results are different from those found in this study, where the best coffee was obtained through the induced fermentation of fruits in complete immersion in water for 24 h, with peeled fruits. Carvalho Neto et al. (2020) report that, the fermentation system also enabled the production of coffee beans with rich aroma composition (including D-Limonene, phenyl-acetaldehyde, and phenylethyl alcohol) and beverages with a remarkable increase in quality compared to the conventional process.

The probable explanation for this difference in results may be that, for each type of microorganism, there may be greater expression in a given environment, and that their variation in the environments implies a change in its interaction with the coffee fruits, thus resulting in different sensory profiles. Mota et al. (2020) report that, the response to the addition of yeasts interacts with the different processes, so that *S. cerevisiae* inoculation was the most suitable for pulped coffee and *T. delbrueckii* inoculation showed the best performance in natural coffee. However, yeast inoculation always enhanced coffee beverage quality.

Thus, it is emphasized that, in the studies mentioned above, with yeast isolated from the coffee crop itself, which induced the desirable fermentation, corroborate the results found in this study, so that the best post-harvest management technique for the highest quality of the coffee beans was without the addition of any exogenous component.

CONCLUSION

The wet processing of coffee fruits without the addition of extracts, immersed in water for 24 h, yielded better sensory quality.

The addition of *Ananas comosus* extract in the induced coffee fermentation, implies a reduction in the sensory quality of the beverage.

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REFERENCES

BORÉM, F.M. **Pós-colheita do café.** Lavras: UFLA, 2008. 631p.

BRESSANI, A.P.P.; MARTINEZ, S.J.; EVANGELISTA, S.R.; DIAS, D.R.; SCHWAN, R.F. Characteristics of fermented coffee inoculated with yeast starter culturesusing different inoculation methods. **LWT - Food Science and Technology**, v.92, n.1, p.212-219, 2018.

CAIXETA, G.Z.T.; GUIMARÃES, P.T.G.; ROMANIELLO, M.M. Gerenciamento como forma de garantir a competitividade da cafeicultura. **Informe Agropecuário**, v.29, n.247, p.14-23, 2008.

CARVALHO NETO, D.P.; PEREIRA, G.V.M.; FINCO, A.M.O.; RODRIGUES, C.; CARVALHO, J.C.; SOCCOL, C.R. Microbiological, physicochemical and sensory studies of coffee beans fermentation conducted in a yeast bioreactor model. **Food Biotechnology**, v.34, n.2, p.172-192, 2020.

CONAB. COMPANHIA NACIONAL DE ABASTECIMENTO. **Acompanhamento de safra brasileira de café.** Safra 2020. v.6, n.3, p.1-54, 2020.

CRUZ, C.D. **Programa Genes:** biometria. Viçosa: Editora UFV, 2006. 382p.

De BRUYN, F.; ZHANG, S. J.; POTHAKOS, V.; TORRES, J.; LAMBOT, C.; MORONI, A.V.; CALLANAN, M.; SYBESMA, W.; WECKX, S.; VUYST, L. Exploring the impacts of postharvest processing on the microbiota and metabolite profiles during green coffee bean production. **Applied and Environmental Microbiology**, v.83, n.1, e02398-e2416, 2017.

DE MARIA, C.A.B.; TRUGO, L.C.; AQUINO NETO, F.R.; MOREIRA, R.F.A.; ALVIANO, C.S. Composition of green coffee water-soluble fractions and identification of volatiles formed during roasting. **Food Chemistry**, v.55, n.3, p.203-207, 1996.

EVANGELISTA, S.R.; MIGUEL, M.G.C.P.; CORDEIRO, C.S.; SILVA, C.F.; PINHEIRO, A.C.M.; SCHWAN, R.F. Inoculation of starter cultures in a semi-dry coffee (*Coffea arabica*) fermentation process. **Food Microbiology**, v.44, n.8, p.87-95, 2014.

EVANGELISTA, S.R.; MIGUEL, M.G.C.P.; SILVA, C.F.; PINHEIRO, A.C.M.; SCHWAN, R. F.Microbiological diversity associated with the spontaneous wet method of coffee fermentation. **International Journal of Food Microbiology**, v.210, n.1, p.102-112, 2015.

FASSIO, L.O.; PEREIRA, R.G.F.A.; MALTA, M.R.; LISKA, G.R.; SOUSA, M.M.M.; CARVALHO, G.R.; PEREIRA, A.A. Sensory profile of arabica coffee accesses of the germplasm collection of Minas Gerais - Brazil. **Coffee Science**, v.14, n.3, p.382-393, 2019.

FERREIRA, A.D.; MENDES, A.N.G.; CARVALHO, G.R.; BOTELHO, C.E.; GONÇALVES, F.M.A.; MALTA, M.R. Sensory analysis of different Bourbon coffee genotypes. **Interciencia**, v.37, n.5, p.390-394, 2012.

FERREIRA, D.F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v.35, n.6, p.1039-1042, 2011.

GONZÁLEZ-ARENZANA, L.; SANTAMARÍA, R.; ESCRIBANO-VIANA, R.; PORTU, J.; GARIJO, P.; LÓPEZ-ALFARO, I.; LÓPEZ, R.; SANTAMARÍA, P.; ROSA GUTIÉRREZ, A. Influence of the carbonic maceration winemaking method on the physicochemical, colour, aromatic and microbiological features of tempranillo red wines. **Food Chemistry**, v.319, n.1, p.126569, 2020.

IAMANAKA, B.T.; TEIXEIRA, A.A.; TEIXEIRA, A.R.R.; COPETTI, M.V.; BRAGAGNOLO, N.; TANIWAKI, M.H. The mycobiota of coffee beans and its influence on the coffee beverage. **Food Research International**, v.62, n.8, p.353-358, 2014a.

IAMANAKA, B.T.; TEIXEIRA, A.A.; TEIXEIRA, A.R.R.; VICENTE, E.; FISVAD, J.C.; TANIWAKI, M.H.; BRAGAGNOLO, N. Potential of volatile compounds produced by fungi to influence sensory quality of coffee beverage. **Food Research International**, v.64, n.10, p.166-170, 2014b.

JACKELS, S.C., JACKELS, C.F. Characterization of the coffee mucilage fermentation process using chemical indicators: A field study in Nicaragua. **Journal of Food Science**, v.70, n.5, p.321-325, 2005.

LINGLE, T. R. **The coffee cupper's handbook:** systematic guide to the sensory evaluation of coffee's flavor. 4th ed. Long Beach: Specialty Coffee Association of America, 2011. 66p.

MALTA, M.R.; ROSA, S.D.V.F.; LIMA, P.M.; FASSIO, L.O.; SANTOS, J.B. Changes in quality of coffee submitted to different forms of processing and drying. **Revista Engenharia na Agricultura**, v.21, n.5, p.431-440, 2013.

MELO PEREIRA, G.V.; NETO, E.; SOCCOL, V.T.; MEDEIROS, A.B.P.; WOICIECHOWSKI, A.L.; SOCCOL, C.R. Conducting starter culture-controlled fermentations of Coffee beans during on-farm wet processing: Growth, metabolic analyses and sensorial effects. **Food Research International**, v.75, n.1, p.348-356, 2015.

MOTA, M.C.B.; BATISTA, N.N.; RABELO, M.H.S.; RIBEIRO, D.E.; BORÉM, F.M.; SCHWAN, R.F. Influence of fermentation conditions on the sensorial quality of coffee inoculated with yeast. **Food Research International**, v.136, n.1, p.109482, 2020.

OLIVEIRA, P.D.; BORÉM, F.M.; ISQUIERDO, E.P.; GIOMO, GS.; LIMA, R.R.; CARDOSO, R.A. Physiological aspects of coffee beans, processed and dried through different methods, associated with sensory quality. **Coffee Science**, v.8, n.2, p.203-211, 2013.

PEREIRA, D.R.; AGUIAR, J.A.R.; NADALETI, D.H.S.; FASSIO, L.O.; CARVALHO, J.P.F.; CARVALHO, S.P.; CARVALHO, G.R. Morphoagronomic and sensory performance of coffee cultivars in initial stage of development in cerrado mineiro. **Coffee Science**, v.14, n.2, p.193-205, 2019a.

PEREIRA, G.V.M.; SOCCOL, V.T.; PANDEY, A.; MEDEIROS, A.B.P.; LARA, J.M.R.A.; GOLLO, A.L.; SOCCOL, C.R. Isolation, selection and evaluation of yeasts for use in fermentation of coffee beans by the wet process. **International Journal of Food Microbiology**, v.188, n.20, p.60-66, 2014.

PEREIRA, L.L.; GUARÇONI, R.C.; MOREIRA, T.R.; BRIOSCHI JR, D.; MARCATE, J.P.P.; SOUSA, L.H.B.P.; MORELI, A.P.; DEBONA, D.G.; TEN CATEN, C.S. Sensory profile of fermented arabica coffee in the perception of American cupping tasters. **Agricultural Sciences**, v.10, n.3, p.321-329, 2019b.

PEREIRA, L.L.; GUARÇONI, R.C.; PINHEIRO, P.F.; OSÓRIO, V.M.; PINHEIRO, C.A.; MOREIRA, T.R.; TEN CATEN, C.S. New propositions about coffee wet processing: chemical and sensory perspectives. **Food Chemistry**, v.310, n.1, p.125943, 2020.

RIBEIRO, L.S.; RIBEIRO, D.E.; EVANGELISTA, S.R.; MIGUEL, M.G.C.P.; PINHEIRO, A.C.M.; BORÉM, F.M.; SCHWAN, R.F. Controlled fermentation of semi-dry coffee (*Coffea arabica*) using starter cultures: A sensory perspective. **LWT - Food Science and Technology**, v.82, n.1, p.32-38, 2017.

RODRIGUEZ-ZUNIGA, U.F.; FARINAS, C.S.; BERTUCCI NETO, V.; COURI, S.; CRESTANA, S. Produção de celulases por *Aspergillus niger* por fermentação em estado sólido. **Pesquisa Agropecuária Brasileira**, v.46, n.8, p.912-919, 2011.

SILVA, C.F. **Microbial activity during coffee fermentation.** Chapter 11. p.397-430. In: Fermented Foods and Beverages Series: Cocoa and Coffee Fermentations. SCHWAN, R.F.; FLEET, G.H. (Eds.). CRC Press, Taylor & Francis Group: Boca Raton, 2014, 611p.

TAVEIRA, J.H.S.; BORÉM, F.M.; ROSA, S.D.V.F.; OLIVEIRA, P.D.; GIOMO, G.S.; ISQUIERDO, E.P.; FORTUNATO, V.A. Post-harvest effects on beverage quality and physiological performance of coffee beans. **African Journal of Agricultural Research**, v.10, n.12, p.1457-1466, 2015.