academicJournals

Vol. 9(4), pp. 230-236, April, 2015
DOI: 10.5897/AJFS2014.1221
Article Number: 62868E051608
ISSN 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Effects of coffee processing technologies on physico-chemical properties and sensory qualities of coffee

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Received 21 October 2014; Accepted 16 March 2015

The study aimed at comparing the effects of three coffee pulping methods on the physico-chemical properties and sensory qualities of coffee. The coffee cherries were processed by disc pulper, drum pulper and eco-pulper methods which varied on mode of operations and mucilage removal methods. The coffee parchment were dried to moisture content of 10 ± 1% and green coffee beans were evaluated for parameters including moisture content, mass, volume, density, pH, titratable acidity, protein, sucrose and lipids content of green coffee beans. The parameters such as moisture, mass, volume and density were determined by actual measurements. Protein was determined by Kjeldhal method, lipids were extracted by Soxhlet method and sucrose extracted and determined by HPLC. The pH showed some significant difference ($p<0.05$) between the treatments. There was no significant difference on other parameters such as mass, volume, density and titratable acidity, protein, lipids and sucrose. The processing methods showed similar levels on the scores of sensory attributes analyzed by qualified panelist and the scores varied between 7.0-10. The final quality was not significantly different between the processing methods and no defects and faults noted in the samples. It was concluded that the three processing methods do not vary on the levels of physico-chemical components of coffee and gives similar characteristics on sensory attributes and final quality of coffee beverage.

Key words: Coffee processing, pulping methods, fermentation, physico-chemical composition, sensory quality.

INTRODUCTION

Coffee quality is associated to a set of factors that involve physico-chemical and sensorial aspects which, in turn, depend on the post-harvest handling and processing (Coradi et al., 2007; Afonso Júnior, 2001, Lima et al., 2008). Wet processing is more commonly preferred than the dry method due to its production of good quality coffee. Wet coffee processing consists in removing pulp and skin from fresh berries using a pulping machine (Murthy and Naidu, 2011). These machines remove the skin and pulp from coffee cherries leaving viscous

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mucilage adhering to the parchment. Mucilage is traditionally removed by use of natural fermentation process where the natural micro flora degrade it hence facilitating its elimination by washing (Murthy and Naidu, 2011, Avallone, 2000).The whole process entails use of large quantities of water during pulping, washing and grading stages which contributes to the pollution of water in countries where it is commonly used (Gonzalez-Rios et al., 2007, Bailly et al., 1992). A new technology called ecological processing was developed in Colombia and Brazil, utilizes little water, pulp coffee and removes mucilage by mechanical processes without the fermentation stage (Roa et al, 2012, Gonzalez-Rios et al, 2007, Puerta-Quintero, 1999). Fermentation is a crucial stage in coffee wet processing because apart from enhancing the removal of mucilage from parchments it is reported to improve the quality of coffee (Nigam and Singh, 2014). Whereas the disc and drum pulpers utilizes fermentation during mucilage removal, the eco-pulper method uses mechanical process, hence the coffee produce may vary in terms of the physico-chemical properties which may leads to variations in the sensory quality of coffee. There is limited information on the effects of the new technology on the physico-chemical composition of coffee and the sensory characteristics of coffee brew. This study was undertaken to investigate the effects of the disc, drum and eco-pulper methods on the physic-chemical composition and sensory qualities of coffee.

METHODOLOGY

Site and sample preparation

Coffee cherries of variety commonly referred as SL 28 (Arabica coffee) were harvested during the short and peak harvesting seasons between the year 2012 and 2013. The coffee cherries were harvested from Dedan Kimathi University farm located in Nyeri County Kenya (0° 25' 0" S / 36° 57' 0" E). Ripe cherries were obtained from coffee plants grown on the same field, by selective picking method, sorted and processed by three different pulping methods which include the disc pulper, drum pulper and an eco-pulper method. Disc pulper method was done by continuous pulping operation with water involve in pulping, transport and grading of parchment. The parchments obtained were put in plastic containers with perforation at the bottom and allowed to ferment by dry method for 16 to 18 h. Once fermentation was complete, the parchments were washed to remove the mucilage and graded to have heavier and the lighter parchment. The heavier parchments were selected for research and transferred to the drying tables for drying in the sun to attain moisture content of 10 ±1%.

Drum pulper method was done by use of a motorized manual pulping machine and little water used during pulping. The parchment obtained were subjected to fermentation in plastic containers with perforation at the bottom to allow dry fermentation for 16 to 18 h. Once fermentation was complete, the parchment were washed and graded to separate lighter and heavier parchment. The heavier parchments were selected and transferred to the drying tables for drying in the sun to the required moisture content of 10 ± 1%. The eco-pulper method was done by first sub-Merging coffee cherries with water in a tank to separate the heavier and lighter cherries which were then pulped separately using an eco-pulper.

Heavier cherries were selected for research and after pulping the parchment were passed through a demucilager unit which removes the mucilage mechanically with some water poured continuously to clean the parchment. Clean coffee parchments were put in trays and transferred to drying tables for drying in the sun to the required moisture content of 10 ± 1%. The dry parchments from the three processing methods were package in sealed polythene bags and stored in a freezer at -18°C until time for analysis.

Analysis of composition

Chemicals

The chemical used in the analysis of parameters such as proteins, lipids and sucrose included; concentrated sulphuric acid, absolute ethanol, concentrated hydrochloric acid, hexane, sodium hydroxide, methanol, acetonitrile and were all obtained from Sigma Aldrich (Germany).

Mass, volume and density

Volume of coffee beans were determined according to the method of Dutra et al. (2001) and described by Ismail et al (2013).

Moisture content

The moisture content was determined by use of the methods of Reh et al. (2006) and described by Ismail et al. (2013).

Lipids

The lipids were determined by the Soxhlet method. Some 5 g of powdered samples were refluxed with hexane for 8 h in round bottom flasks. The extracts were then evaporated by a rotary evaporator at 60°C until all the hexane was evaporated. The flasks containing the lipid were dried in an oven until a constant weight was achieved (Ismail et al., 2013).

Crude protein content

Crude protein was determined by Kjeldahl method after digesting samples (1 g) with sulphuric acid and the crude protein calculated as nitrogen × 6.25 according to the method described by AOAC (1995).

Total titratable acidity and pH

This was done according to the method described by Tawfik and EL Bader (2005). The pH was determined by taking 2.25 g of ground samples and mixing with 10 ml of hot water at 80°C, cooled to room temperature and the pH determined. Total titratable acidity was determined by taking 10 g of ground coffee, mixed with 75ml of 80% ethanol and kept under gentle agitation for 16 h. A portion of 25 ml of the extract was diluted to 100 ml with distilled water. Titratable acidity was determined by titrating with 0.1 N sodium hydroxide and three drops of phenolphthalein indicator added. The

results were expressed in percentage.

Determination of sugars

Approximately 1 g of sample was weighed into 250 ml round bottomed flask and 50 ml 95% ethanol added. The mixture was reflux for 1 h, cooled and filtered using filter paper (Whatman No. 42). It was then evaporated to dryness using rotor vapor and reconstituted with 10 ml mobile phase containing acetonitrile: water (75:25) and filtered using micro filter 0.45 and 20 µm injected to HPLC (Knauer, Germany) fitted with a refractive Index detector.

Sensory analysis

The sensorial analysis of coffee samples were carried out to determine the quality of coffee and was done by six qualified cuppers according to the method described by Kathurima et al. (2009). Scores were awarded to each sensorial attribute depending on their intensity in the samples. For each sensorial attribute, the samples received a score on a scale of 0 to 10. The attributes for aroma, aftertaste, acidity, body, flavor, clean, sweet, balance and overall score were evaluated, resulting in a final score count that indicated the quality of coffees.

Statistical analysis

All treatments were done in triplicates and analysis of data evaluated using the statistical package for social scientist (SPSS version 18). Experimental design was performed using complete randomized design (CRD). Analysis of variance (ANOVA) was conducted, and the differences between group means analyzed using the least significant difference (LSD). Statistical significance was established at $p \leq 0.05$.

RESULTS AND DISCUSSION

The data used in this study was for coffee samples obtained during the short and main harvesting seasons and categorized as seasons 1 and 2, respectively. The results for the physical and chemical properties of coffee processed by the three processing methods studied for two harvesting seasons are shown in Table 1. The moisture content for the samples was within the recommended levels of 10-12% (Patui et al., 2014). The eco-pulper method showed slightly lower moisture content than the disc and drum pulper methods, and this could be attributed to faster rate of drying since parchment are exposed to drying immediately after processing. Therefore methods which use fermentation takes long time between 16 and 20 h before coffee parchment is subjected to drying. The level of the moisture content is important for preservation of coffee quality because higher moisture levels than 12% will favour the growth of moulds and cause off flavours affecting the taste qualities of coffee (Bucheli et al., 1998; Ismail et al., 2013). Regarding the mass of coffee samples, disc pulper method showed a significantly lower value than the eco-pulper method during season 1 harvest (Table 1). The same trend was observed in the second season but the values were not significantly different. The reduction in mass in the processes using fermentation may occur mainly due to the effect of microbial activities and leaching of components to the washing water (Roa et al., 2012). However the eco-pulper method, though it uses little water could also lead to losses of components due to the squeezing of coffee parchment through narrow space and high speed rotation which occur in the demucilager. Regarding the volume of coffee samples the results showed no significant differences between the treatments as observed for the two seasons (Table 1). The volume depends on the size of the coffee beans which is mainly influenced more by factors such as climatic and agronomic practices than the processing methods. The values for season 2 was slightly higher than season 1 indicating the effects of the climatic conditions since season 2 occur under the peak period of coffee harvesting with more favorable climatic conditions. In regard to the density, the results were only significant during season 1 with the eco-pulper samples showing higher values compared to the disc pulper samples. This could be attributed to the effect of mass which was higher in the eco-pulper samples than those of the disc pulper samples. This is consistent with the report of Ismail et al. (2013) who also noted that the density of coffee beans are influenced by the mass and not the volume. From this study the values of density varied from 895.81 to 1227.0 kg/cm^3 which was similar to the range reported by other authors such as Ismail et al. (2013) as 992.68 to 1138.25 kg/m^3 and Franca et al. (2005) as 1200 to 1300 kg/m^3 for crude coffee beans.

Considering the pH the results indicate that the disc and drum pulper methods showed significantly lower pH than the eco-pulper samples (Table 1). This is expected because the disc and drum pulper samples were processed through fermentation to remove the mucilage while the eco-pulper samples were processed by mechanical method. Similar observation were reported by other authors such as Ferreira et al. (2013) who explains that pH is reduced in washed coffee due to fermentation. The acids produced during fermentation such as acetic acid may penetrate the husks of the coffee bean influencing the changes observed for pH. This is in agreement with the report of Nigam and Singh (2014). From the study, the pH values range from 5.91 to 6.11 which was within the range reported in the literature such as Franca et al. (2005) reporting pH range of 5.3 to 6.52 and Butt et al. (2011) reporting pH range of 4.89 to 5.98 for green coffee samples. For total titratable acidity, there was no significant difference between the different processing methods studied. The change in titratable acidity could occur due to the levels of acid present in the coffee beans. The common acids present in the coffee beans include; citric, acetic, malic, chlorogenic and quinic acids (Butt et al.,

Table 1. Physico-chemical properties of green coffee from different processing methods for two harvesting seasons.

Parameter	Treatment			
	Seasons	Disc pulper	Drum pulper	Eco-pulper
Moisture %	1	10.84 ± 0.29a	10.33 ± 0.15ab	10.17 ± 0.29b
	2	10.66 ± 0.05a	10.55 ± 0.16a	10.27 ± 0.04a
Mass (g)	1	12.67 ± 0.57b	14.67 ± 0.58ab	16.67 ± 1.15a
	2	16.33 ± 0.58a	17.33 ± 0.58a	18.67 ± 3.06a
Volume (cm^3)	1	14.26 ± 1.4a	14.11 ± 3.43a	13.95 ± 3.21a
	2	17.02 ± 1.97a	17.55 ± 4.06a	15.56 ± 4.48a
Density (kg/m^3)	1	891.82 ± 53.4b	1063.13 ± 146a	1222.62 ± 184a
	2	967.46 ± 102a	972.54 ± 148a	1226.2 ± 152a
pH	1	5.95 ± 0.03b	5.94 ± 0.03b	6.04 ± 0.02a
	2	5.92 ± 0.04b	5.91 ± 0.06b	6.03 ± 0.01a
Titratable acidity (%)	1	1.37 ± 0.22a	1.50 ± 0.13a	1.62 ± 0.13a
	2	1.54 ± 0.08a	1.54 ± 0.34a	2.0 ± 0.25a
Protein %	1	13.17 ± 1.7a	13.83 ± 1.9a	15.57 ± 1.6a
	2	14.26 ± 0.8aA	13.62 ± 1.9a	13.40 ± 1.0a
Sucrose %	1	8.03 ± 0.20a	7.38 ± 0.57a	7.78 ± 0.54a
	2	8.58 ± 0.56a	8.51 ± 0.8a	9.02 ± 0.71a
Fat %	1	17.39 ± 0.64a	17.08 ± 0.39a	17.54 ± 0.29a
	2	17.01 ± 0.01a	16.82 ± 0.5a	16.75 ± 0.14a

[1]Values are means (± SD) of triplicate determinations; [2]Means designated by different letters are significantly different at ($P < 0.05$).

2011). Therefore the processing methods could have similar levels of this organic acids hence no variations in their titratable acidity levels. Ferreira et al. (2013) studying the effects of washed and dry processes did not find any significant differences in total acidity of coffee beans. However Tawfik and EL Bader (2005) reported significant variations between green coffee beans from different varieties. The total acidity and pH are important parameters influencing the quality of coffee beverage.

Protein, fats and sucrose are important components of green coffee which are known to influence the aroma characteristics of roasted coffee. The level of protein content varied from 13.17 to 15.57%. This was within the range reported by Rodrigues et al. (2010) as 9.3 to 20.8% in Arabica coffee. The results indicate that there were no significant differences between the processing methods. The literature report that the enzymes present in green coffee could degrade protein to polypeptides and free amino acids during fermentation for mucilage removal (Nigam and Singh, 2014). From our study, no indication of loss of protein or peptides by the processing methods especially those using fermentation processes. The proteins and peptides may complex with polyphenols (Nigam and Singh, 2014) and hence remain intact in the cell structure.

A study by Arnold and Ludwig (1996) noted that the total concentration of free amino acids and protein content does not change significantly with the chemical reaction occurring during the harvest season and the postharvest processing steps, such as fermentation, drying and storage. Regarding the sucrose content, there was no significant difference between treatments with the values ranging from 7.38 to 9.02%. Similar observation was reported by Knopp et al. (2006) who noted that sucrose and other low molecular weight sugars are not affected by the wet and dry processing of coffee cherries. It could be expected that the processes which use fermentation and excess water during washing loss the sucrose through leaching but no significant loss was observed in the methods studied. Some literature indicates that only soluble sugars such as glucose and fructose may be loss to the processing water and not the

non-reducing sugars such as sucrose (Knopp et al., 2006). This is also supported by the report that metabolic processes occurring at the start of drying takes a short period and mainly affects the reducing sugars such as glucose and fructose and sucrose remains intact as a storage compound (Kleinwachter and Selmar, 2010). Lipids represent a significant part of dry matter in green coffee consisting mainly of triacylglycerol with a range of 13 to 17% (Patui et al., 2014; Joët et al., 2010). The level of lipids in our analysis was slightly higher at a range of 16.75 to 19.60%. Butt et al (2011) reported a range of 9.3 to 12.3%.

The variations could be attributed to the difference in extraction methods, variety or geographical factors (Hurtado and Dorado, 2013). The results also indicate no significant differences between the processing methods on the level of lipid contents of coffee samples. Joët et al. (2010) noted that significant metabolism occurs during wet processing which could lead to increase of chemical substances such as lipids. In our study there was no indication of increase of lipids by the processing methods but the processing methods used may induce similar metabolic processes which result at similar levels of the lipid content. The lipase activity is also reported to be present in the coffee seed but it is mainly induced by germination processes while the presence of parchment prevent oxidation of liphophilic fractions (Patui et al., 2014).

Effects of coffee processing methods on sensory attributes and quality of coffee

The results for analysis of sensory attributes and total quality of coffee are presented in Figures 1 and 2 respectively. The green coffee bean were roasted, ground, brewed and evaluated for cup profiles according to the method described by Kathurima et al. (2009). Ten sensory attributes were evaluated in coffee samples which include aroma, flavor, aftertaste, acidity, body, balance, clean cup, uniformity, sweetness and overall quality. The results of evaluation of the attributes for the different processing methods presented close values (Figure 1). Sensory parameters such as clean cup, uniformity and sweetness were rated with the highest score of 10 for all the treatments. There were no defects noted in all the samples such as stinkers, bitterness and sourness. The cup parameters such as aroma, flavor, aftertaste, acidity, body, balance and overall acceptability were rated as 7.6, 7.6, 7.7, 7.8, 7.6, 7.6 and 7.7 respectively for the eco-pulper samples. For the disc pulper samples, the aroma, flavor, aftertaste, acidity, body, balance and overall acceptability were rated as 7.5, 7.6, 7.6, 7.7, 7.6, 7.6, and 7.6 respectively. Similar levels were observed for the drum pulper samples with the aroma, flavor, aftertaste, acidity, body, balance and over-all being rated as 7.6, 7.7, 7.7, 7.7, 7.6, 7.6 and 7.7 respectively (Figure 1). Generally, the study did not find much variations in the levels of the sensory attributes from coffee brew processed by the disc, drum and eco-pulper methods. Considering each of the sensory attributes it was observed that the eco-pulper showed slightly higher value for the aroma and was at par with the drum pulper for this attributes. For the flavor, the drum pulper showed slightly higher value than the other processing methods. The acidity was slightly higher for the eco-pulper samples than the drum and disc pulper samples.

The processing methods were all at par for the body and balance attributes while the eco-pulper and drum pulper showed slightly higher levels for the overall acceptability of the coffee brew samples. The values for the sensory attributes were not statistically significant between the treatments. This confirms the similarity between the coffee brews processed by the eco-pulper, disc and drum pulper samples. The coffee samples were described to have attractive flavors such as fruity, floral, lemon like and caramel. The eco-pulper samples were described to have well balance body and acidity with floral flavor. The disc pulper samples were described with a winny, fruity and slightly floral flavor. The drum pulper samples also were described to have good body, winny and floral flavor. Hence the processing methods did not vary on the levels of sensory attributes. Due to lack of significant variations between the processing methods on the levels of the sensory attributes, this then confirms their similarity in the levels of the chemical components as observed earlier in green coffee. The results for the final quality of coffee samples are shown in Figure 2. The scores for all the sensory attributes were summed up to give a total score which represents the final quality of coffee. The results indicate that the eco-pulper, disc and drum pulper samples showed a final quality of 83.45, 83.11 and 83.58% respectively in season 1. In season 2 similar results were observed with the eco-pulper, disc and drum pulper giving final quality of 84.0, 83.77 and 83.98% respectively. From the results then it was observed that there were no significant variations in the final quality of coffee processed by the eco-pulper, drum pulper and the disc pulper. The characteristics of the sensory attributes and final quality of coffee mainly depends on the physico-chemical components of roasted coffee which relates to the chemical composition of green coffee (Ferreira et al., 2013; Pimenta, 2003). From our study there were no significant variations in the level of physico-chemical components of green coffee such as protein, sucrose and lipids as observed for the different processing methods. Season 2 samples were also observed to have a slightly higher final quality than season 1 samples. This could be attributed to the for the physical and chemical components between the two seasons. Hence season two which occurs under the peak

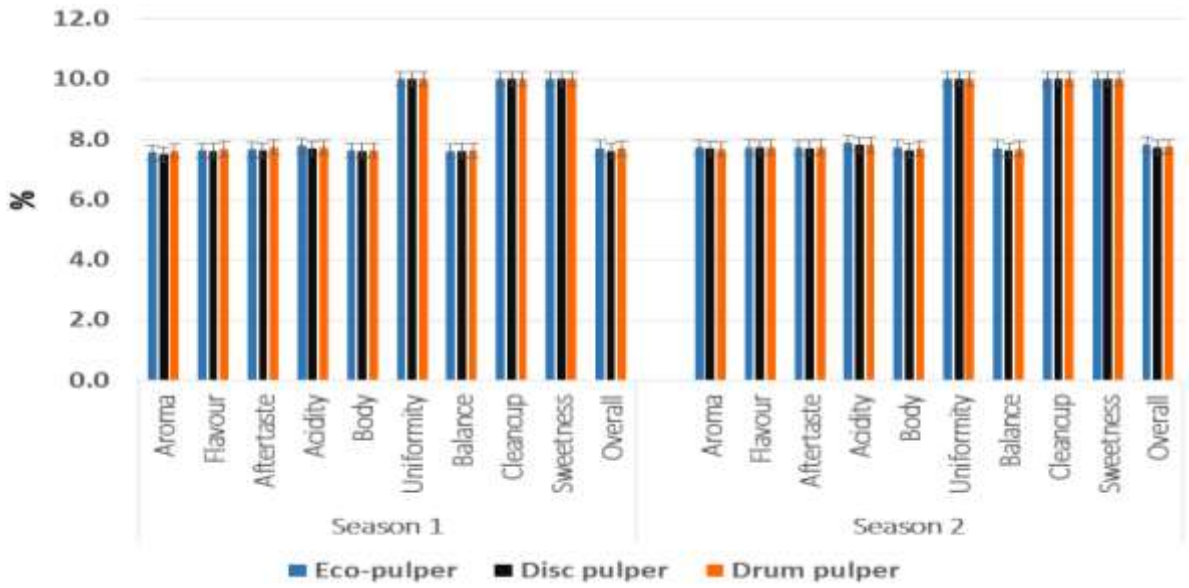

Figure 1. Sensory attributes of coffee beverage processed by three different pulping methods for two harvesting seasons.

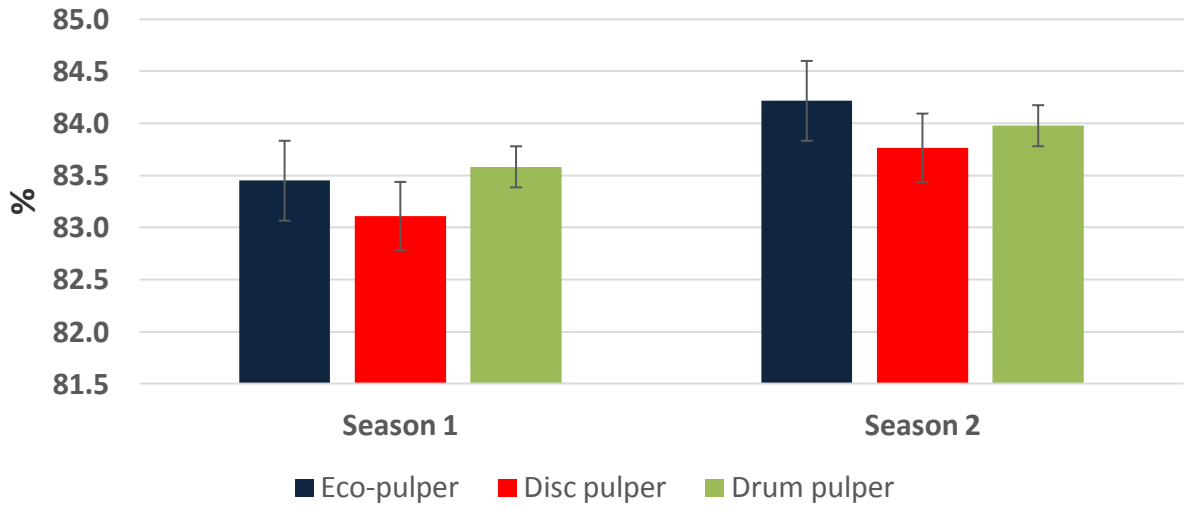

Figure 2. Total quality level of coffee brew processed by three pulping methods for two harvesting seasons.

season of coffee harvesting is observed to have better quality of coffee than the short season of coffee harvesting.

Conclusion

From this study, we investigated the effects of the coffee processing methods, mainly the eco-pulper, the disc and drum pulper on the levels of physico-chemical parameters of coffee such as mass, volume, density, titratable acidity, colour, proteins, sucrose and lipids contents. There was no significant variation between the processing methods on the level of these parameters. The few variations observed for parameters such as density and pH did not have much influence on the sensory attributes and final quality of coffee. The scores for the sensory attributes were very close and final quality of coffee brew was also similar between the treatments.

Therefore, it was concluded that the coffee processing methods such as eco-pulper, disc and drum pulper do not vary on the levels of physico-chemical parameters and gives the same levels of the sensory attributes and final quality of coffee. The important consideration for the processors is the cost effectiveness of the processing methods since all processes gives similar levels of the sensory attributes and final quality of coffee.

Conflict of interest

The authors would like to certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest as regards the subject matter or materials discussed in this manuscript.

ACKNOWLEDGEMENTS

This work was sponsored by the National Council of Science and Technology (NACOSTI). We acknowledge the services of technical staff of Coffee Research Foundation and Jomo Kenyatta University of Agriculture and Technology.

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