J. Hortl. Sci.
Vol. 16(2) : 292-300, 2021

Original Research Paper

Physical quality of coffee bean (*Coffea arabica* L.) as affected by harvesting and drying methods

Chala T.[1], Lamessa K.[*2] and Jalata Z[2]

[1]Bega District Agricultural Office, Coffee and Spices Expert, West Wollega, Ethiopia
[2]Department of Plant Sciences, Faculty of Agriculture, Shambu Campus, Wollega university, Ethiopia
*Corresponding author Email : klamessa@gmail.com

ABSTRACT

Coffee is a stimulant crop with high socio-economic cultural value including economical significance in Ethiopia. This study was conducted in 2019-2020 to investigate the effect of harvesting methods and drying surfaces on the physical quality of the coffee beans. The experiment was carried out with two factors, harvesting methods and drying surfaces laid out in a two factorial completely randomized block design with three replications using a landrace coffee variety. The result showed that the interaction of harvesting methods and drying surfaces was highly significant (P<0.01) for coffee bean size and dried coffee berry weight. The highest beans retained above screen were recorded from the interaction of mesh wire (90%) and cemented drying (89%) surfaces with selective harvesting methods. The highest dried coffee berry weight (69.33 gm) were attained from the interaction of selective harvesting with mesh wire drying surfaces. The lowest dried coffee berry weight (63.79 gm) were attained from the interaction of strip harvesting with tin drying surfaces. Significant (P<0.05) variation for primary defects, length of drying period were recorded. Higher length of drying periods (41.67 days) was recorded from the interaction of mesh wire drying surfaces with selective harvesting method and the lowest (20.33 days) was recorded from the interaction of tin drying surfaces with strip harvesting method. The highest percentage of primary defected beans were recorded from the interaction of selective harvesting methods with mesh wire drying surfaces (15%) and the lowest number were recorded from strip harvesting method with drying on plastic (5%). Therefore, it can be concluded that using the interaction of selective harvesting and drying on mesh wire is better for optimum physical quality of coffee in the studied area

Keywords: Coffee bean size, drying surface, ethiopia, export, harvesting methods and physical quality,

INTRODUCTION

Ethiopia is naturally endowed with a suitable climate with a distinctive coffee profile and has the potential to produce large amounts of differentiated high-quality green coffee. But currently, Ethiopia's coffee qualities are quite average and need special attention to produce high-quality coffee to be competitive in today's world market (Asfaw, 2018). Coffee is the number one foreign exchange earning export commodity of Ethiopia. Almost 2% of the world's coffee comes from Ethiopia. Over 60% of the country's foreign exchange is obtained through the export of coffee. A quarter of the population is directly or indirectly engaged in the production, processing, and marketing of coffee (Chauhan *et al.*, 2015).

Coffee is grown by 6.3 million smallholder farmers in Ethiopia in an area of 758,523 ha with a production of 4.8 million qt and an average productivity of 6.36 qt/ha (CSA, 2020). Coffee is the most important commodity and there is huge potential to increase coffee production as the country is endowed with suitable agro-ecology, climatic, soil fertility, indigenous quality planting materials, and sufficient rainfall in the coffee-growing belts of the country. And, there is high national and international demand for the Ethiopian coffee product, increasing interest of private sector with high investment potential (Berhanu, 2017). Ethiopia produces a large volume of coffee beans every year with 397,500 tons in 2014 alone, and ranking first in Africa and fifth in the world (ICO, 2015). However, coffee supplied and traded in the local market is usually has a lower quality. Coffee on the local market is mainly coffee destined for export through the Ethiopian Commodities Exchange (ECX) market but failed to meet ECX's quality standards (Asfaw, 2018) for export and got rejected. Quality is an important attribute of coffee and it is currently becoming even more important than in the past as coffee industry is generally going through a worldwide surplus production crisis (Petit *et al*., 2007).

Wollega is also a potential coffee growing area of Western Ethiopia (Stieger *et al.,* 2002). Though coffee quality is affected in several ways, the agronomic practices followed during harvesting, processing, and handling practices also influence its quality. According to Desse's (2008) report, poor harvesting practices such as stripping, collecting dropped fruits from the ground, improper postharvest handling practices such as bad processing and drying on the bare ground resulted in the low-quality green coffee bean. Among them, type of harvesting and drying methods used are important. However, there is little information on the effect of different practices such as harvesting methods and drying surface on coffee quality. Therefore, this study was initiated to investigate the influence of harvesting methods and drying surfaces on the physical quality attributes of coffee in Begi district West, Wollega of Ethiopia.

MATERIALS AND METHODS

Description of the study area: The study site was in Begi district, West Wollega zone, Oromia Regional State of Ethiopia which is one of the major coffee-producing districts. The selected district represents the agro-ecological zones where coffee is produced. The agroecology of the area is semi-humid and the annual rainfall ranged between 1300-1500 mm per year and the mean annual temperature is 20-28^{0}C. Geographically it is located between latitude of 9^{o}26'North and longitude 34^{o}32'East at altitude range of 1768 meters above sea level.

Treatments and experimental design: The local land race of coffee (*Coffea arabica* L.) was used in the present study. The study consists of two factors *viz*., the harvesting method and drying surfaces. Two harvesting method *viz.,* selective and strip harvesting were tested. Under strip harvesting method, cherries were harvested when 75% of the cherries reached at full ripe stage whereas in selective picking the cherries were harvested as they attained full red ripe stage. Six drying surfaces *viz.*, bamboo mats, bare ground, cemented floor, mesh wire, plastic sheet and tin sheet were tested. The cherries harvested using both methods were spread out to dry in the sun on the six drying surfaces. They were stirred regularly to promote even drying, prevent fermentation and the development of mold in each treatment. Then each sample cherries were dried till their outer shell skin became dark brown and brittle. When the approximate moisture content of 11.5% was attained, dried coffee cherries were collected and de-hulled with mortar carefully and cleaned (Boot, 2006). Each of the drying surfaces had an area of 1m x 1m = 1m^2.

Laboratory analysis: Clean coffee bean sample of 500 g was taken from each treatment combination based on sampling procedure set by Ethiopian standard (ESBN 8.001), which is on the basis of drawing 3 kg per 10 tons. Representative samples were assigned an arbitrary code in order to secure an unbiased judgment and brought to coffee quality laboratory of the Jimma Agricultural Research Center where the green coffee beans were evaluated for different raw quality attributes. The moisture content of the sample was checked using Electronic Rapid Moisture Tester (HE 50, Germany) to make the uniform required moisture level of all samples.

Data collection: The data on length of drying period (days), weight of dried coffee berry (g), bean moisture content (%), dried bean weight (g), primary defect (count), secondary defect (weight), odor, coffee aroma and coffee flavor were collected according to their respective procedures.

Data Analysis: The various coffee quality data collected were subjected to analysis of variance using statistical procedures as described by Gomez and Gomez (1984) using SAS 9.3 version. The differences between and among treatment means were compared using the least significance difference test at 5% of significance when the ANOVA shows the presence of significant difference.

RESULTS AND DISCUSSION

Bean size screen (%): The main effect of harvesting methods and drying surfaces as well as their interaction were highly significantly (P<0.01) (Table 1) influencing the bean screen size. Moreover, the interaction effect of harvesting methods and drying surfaces on the total percentage of bean size retained above screen size 14 ranged from 90% to 73%. The highest beans retained above screen were recorded with wire mesh drying surfaces with selective harvesting methods (90%). However, it was at par with cemented floor. The result indicated that coffee beans harvested in selective picking and treated with different drying surfaces met the export standards except when selective beans dried on tin surfaces (82.3%) (Table 2). The present finding is in agreement with Mekonnen (2009) who reported the highest percentage of beans retained above screen were recorded when different varieties of coffee beans were harvested. All the interaction of strip harvesting methods with respective drying surfaces ranged from 75.67% to 73% (Table 2) which failed under the category of rejected commercial coffee based on ECX (2010) standard. According to ECX (2010), any Ethiopian coffee export shall have a minimum of 85% of bean weight remaining on the top of screen 14 (Table 2). Similarly, Mohammedsani *et.al*. (2017) reported bean size was significantly influenced by harvesting methods and the interaction of harvesting and postharvest processing methods. Selective harvesting of red fruits produced a uniform bean size that is above the minimum required bean screen size. To improve quality coffee, traders practice some value-adding activities like removing the defect and undersized beans thorough cleaning and sorting (Anteneh, 2011), and Belete (2014) indicated coffee with larger beans usually get a good grade and fetch a higher price than smaller ones. The current study confirmed the report of Getachew *et.al* (2015) who indicated drying coffee on wire mesh and bamboo mats with a thin layer of thickness earned above screen size of beans (>85%).

Dried bean weight : The result showed a significant difference in 100 bean weight due to the main effect of harvesting methods but a non-significant result was obtained due to the main effect of drying surfaces and their interactions (Table 1). And, from this study, the highest 100-bean weight was recorded when coffee was harvested by selective methods (16.51 g) and the lowest recorded in strip harvesting methods (15.39 g) (Table 3). Similarly, Vaast *et.al*. (2006) indicated harvesting methods significantly influenced the bean weight of coffee due to the lower biochemical composition of the bean, hence reducing the cup quality. This study confirms also the finding of Mohammedsani *et.al., (*2017), the highest bean weight was obtained from selective harvesting compared to strip harvesting. This study showed the selective harvesting method was 7% more than strip harvesting (Table 3). Another report by Boot (2006) showed that the weight of ripe cherry was more by 20% than that of immature cherry. This might be due to the fact that on bamboo, cement, and mesh wire there was a gradual moisture loss and less burning effect, whereas on a tin bed, there was a burning effect on coffee berry which may decrease the weight of coffee seed. The result regarding drying surfaces was supported by Mohammedsani *et.al.,* (2017). And, report of Wintegens, (2004) and Yigzaw (2014) showed that Arabica coffee average bean weight with values ranging between 9.2 g and 18.2 g.

Primary defects: The analysis of variance revealed that the main effect of harvesting methods and drying surfaces were highly significant (P<0.01) on the primary defect. And, the interaction effect of harvesting methods and drying surfaces were also significant (P<0.05) for primary defect (Table 1). The highest percentage of many defected beans was recorded on selective harvesting methods and drying on a wire mesh (15) and the lowest number of a defected bean is recorded from strip harvesting with drying on plastic (5) (Table 2). This might be because unripe cherries lead to light-green beans, which when dried, become black and these beans are counted as defective in strip harvesting. This study is in agreement with the finding of Bee *et al.,(*2005).

Table 1. Mean squares values of raw quality attributes of coffee as affected by harvesting methods and drying surfaces in Begi district, West Wollega Zone, Ethiopia

Raw quality attributes	Harvesting methods (HM) (1)	Drying surfaces (DM) (5)	HM* DM (5)	Residual (22)	CV (%)
Bean size	1332.25**	13.89**	15.31 **	0.596	1
SED (±)	0.257	0.924	1.307		
Bean weight (gram)	11.177*	0.538^{ns}	1.92^{ns}	5.45	3.1
SED (±)	0.286	0.166	0.843		
Primary defect (%)	306.25**	14.65**	1.45 *	0.523	7.2
SED (±)	0.241	0.417	0.59		
Secondary defect (%)	361**	17.4**	2^{ns}	1.364	11.7
SED (±)	0.389	0.674	0.953		
Length of drying period (days)	215.11**	230.73**	1.178*	0.371	2.3
SED (±)	0.352	0.203	0.497		
Dried coffee berry weight (gram)	29.16**	6.508**	2.67**	0.16	0.6
SED (±)	0.23	0.134	0.327		
Odor (%)	21.78**	5.24**	0.44^{ns}	0.78	10.3
SED (±)	0.294	0.509	0.72		
Acidity	25.00**	1.2^{ns}	1.6^{ns}	1.84	10.1
SED (±)	0.452	0.783	1.108		
Body	2.2^{ns}	4.00^{ns}	1.00^{ns}	2.636	2.2
SED (±)	0.54	0.94	1.33		
Flavor	20.25	0.85	1.65	2.159	10.8
SED (±)	0.49	0.85	1.2		

* Significant at P<0.05, ** highly significant at P<0.01, ns= non-significant difference, Numbers in parenthesis indicates degree of freedom. CV (%) = coefficient of variation in percent, Sed (±) = Standard error of difference.

Table 2. Bean size screen using ECX (2010) standard

Harvesting methods	Drying methods	Average value analysis screen beans size	ECX (2010) standard
Selective harvesting	Bamboo Mats	86.67	
	Plastic Sheet	85.00	
	Cement	89.00	Export Standard
	Wire Mesh	90.00	
	Bare Ground	84.67	
	Tin	82.00	
Strip harvesting	Bamboo	75.67	
	Bare Ground	75.67	
	Cement	73.55	Rejected for Export
	Wire Mesh	73.67	
	Plastic Sheet	73.00	
	Tin	73.33	
	Mean	80.19	
	LSD (5%)	1.307	
	CV (%)	1.00	

ECX (2010) stated that Moisture and screen analysis are the two requisites before grading any coffee. The moisture content should be less than 11.5 percent, while the size of the bean should be above screen size 14 for 85 percent of the bean sample.

Table 3. The main effect of harvesting method and drying surfaces on raw and physical quality attributes of coffee in Begi district, Ethiopia

Treatments	Bean weight	Secondary defect	Odor	Body	Flavor
Harvesting method (HM)				to the power	
Selection	16.51	13.17	9.33^{ab}	13.67	14.33^{a}
Strip	15.39	6.83	7.78^{b}	13	12.83^{b}
LSD (5%)	0.34	0.807	0.61	NS	1.016
SED			0.294	0.541	0.49
Drying surface (DS)					
Bamboo	16.34	11.00	9.667^{a}	13.5	13.5
Bare Ground	15.81	8.00	9.667^{a}	12.5	13
Cement	16.16	11.50	9^{abc}	14	14
wire mesh	16.13	12.00	9.33^{ab}	14	13.5
Plastic sheet	15.70	8.50	8.33^{acb}	13	13.5
Tin	15.58	9.00	7.667^{bc}	13	14
LSD (5%)	ns	1.39	1.056	NS	NS
HM*DM	ns	ns	NS	NS	NS
CV (%)	3.10	11.70	10.3	12.2	10.8

Means followed by the same letter(s) within rows and columns are not significantly different at P d" 0.05 level of significance, LSD= Least significant differences=Non-significant, CV (%) = coefficient of variation in percent

Similarly, with the report of Barel and Jacquet (1994), selective harvesting of coffee produced the best quality coffee by decreasing the percentage of defective coffee beans. Also, Berhanu *et al*., (2014) also indicated that inappropriate post-harvest management practices increased the number of defective coffee beans. Moreover, Tesfaye (2006) and Negussie *et.al*. (2009) stated that properly processed coffee is with very few defective beans.

Secondary defects

The result showed that there was a highly significant (Pd"0.01) variation of secondary defects due to the main effect of harvesting methods and drying surfaces. However, the interaction effect of harvesting methods and drying surfaces did not significantly affect secondary defects (Table 1). Selective harvesting had a high mean value of 13.17% indicating relatively pure coffee beans. However, the lower mean value (6.83%) was recorded from strip harvesting (Table 3), which indicated a high number of secondary defects due to improper harvesting. This showed that selective harvesting had more coffee beans free from secondary defects as compared to strip harvesting in dry-processed coffee. This is because selective harvesting involves only picking off the red, fully ripe, and normal cherries carefully from the tree while strip harvesting involves collecting of entire coffee bean just by one pass through cropping season. This result is in line with Hicks (2002) who described that although selective picking is more expensive, it can produce the best results of coffee by reducing the number of defects thereby increase the overall quality of coffee which is competent in the world market. And, Hicks (2002) reported that coffee that has been inappropriately dried would become brittle and produce too many broken beans that are considered as a secondary defect during hulling. Similarly, Olamcam (2008) result showed that the coffee well harvested and properly processed has no or very few broken beans and free of foreign matter.

Length of drying periods: The analysis of variance revealed that the length of drying periods was highly significantly (P<0.01) different due to the main effect of drying surfaces and harvesting methods and significant (P<0.05) difference due to the interaction effect of both factors (Table 1). Higher length of drying periods (41.67 days)was recorded from the interaction of wire mesh drying surfaces with selective harvesting method and the lowest (20.33 days) was recorded from the interaction of tin drying surfaces with strip harvesting method but statically at par with the interaction of plastic drying surface with strip harvesting method (20.67) (Table 4). Harvesting red cherry would prolong the drying periods than harvesting in a strip. Besides, at the full maturity stage, there might be an increment of moisture and the development of luxurious mucilage. This result agrees with the findings of Berhanu *et.al.* (2014) that the shortest time drying periods were recorded when coffee was dried in bricks off the floor then raised bed. FAO (2006) and Martin *et al*. (2009) also reported coffee dried on a flat surface more quickly than that dried on raised-bed surfaces like mesh wire and bamboo mats.

Table 4. Interaction effect of the harvesting method and drying surfaces on the primary defect, length of drying (in days), and dried coffee berry weight at Begi West Wollega Zone, Ethiopia.

Drying surfaces	Harvesting methods					
	primary defect		length of drying (in days)		Dried coffee berry weight	
	Selective	Strip	Selective	Strip	Selective	Strip
Bamboo	12.00	8.00	28.00	21.67	65.67	65.30
Bare ground	12.00	6.00	27.33	23.33	65.73	63.80
Cement	15.00	9.00	26.67	22.67	67.53	64.90
Wire mesh	15.00	9.00	41.67	36.67	69.33	65.53
Plastic	12.00	5.00	25.33	20.67	65.53	65.20
Tin	12.00	6.00	25.67	20.33	65.50	63.76
Mean	-		26.67		65.65	
LSD (5%)	1.224		1.03		0.679	
CV (%)	7.20		2.30		0.60	

LSD= Least significant difference, CV= Coefficient of variation

Dried coffee berry weight

The analysis of variance revealed that the weight of dried coffee berry was highly significant ($P<0.01$) different due to the main effect of harvesting methods and drying surfaces. And, the interaction effect of harvesting methods and drying surfaces was also highly significant ($P<0.01$) on dried coffee berry weight (Table 1). The highest dried coffee berry weight (69.33) and lowest (63.76) was recorded as an interaction of Selective harvesting with mesh wire bed and strip harvest with tin drying, respectively (Table 4). This was because in selective harvesting the only red, matured and disease-free coffee berry was harvested.

The present finding supports Clifford (1985), who reported acceptable dry matter loss within the ranges between 35 and 14%. Mekonen (2009) also indicated that selectively harvested coffee of different drying surfaces showed significant variation in coffee weight by recording the highest percentage of beans retained above the screen. ITC (2011) also indicated that picking immature cherries with mature cherries could cause a reduction of the weight of the beans. Similarly, Boot (2006) reported that under almost all conditions, the specific weight of ripe cherry is greater than that of an immature cherry, it is heavier, weighing up to 20% more

Odor: The analysis of variance revealed there was a highly significant variation (Pd"0.01) for odor due to the main effect of coffee harvesting methods and drying surfaces (Table 1). However, their interaction effect showed non-significant variations for odor. For selective harvesting (9.33) the mean values of odor were higher than strip harvesting (7.78). For drying surfaces, the highest mean value of odor was recorded when beans dried on bamboo and wire mesh and the lowest was recorded in bare ground and tin (Table 3) showing that the odor was affected due to improper harvesting and drying surfaces. A similar finding was reported by Olamcam (2008) indicating properly harvesting beans make free of unpleasant (bad) smells. Endale *et.al.,*(2008) reported that coffee with better management in each stage starting from harvesting until cupping turns out to have a better odor. Subedi (2010) reported coffee dried on bricks floor in contact with soil becomes dirty and blotchy resulting in a dull odor. Using incongruous drying surfaces and methods reduced raw and cup quality of coffee by producing off-flavor, abnormal color, and unpleasant odor, and finally cup cleanness (Mohammedsanni *et.al.,* 2017).

Flavor: The result showed that the flavor was highly significantly (P<0.01) different due to the main effect of harvesting methods. But, non-significant due to drying surfaces and interaction effect of drying surfaces with harvesting methods (Table 1). The highest percentage number of flavors is recorded in selectively harvested coffee (14.33) and the lowest in the number of flavors is recorded in the strip harvesting method (12.83) (Table 4). In strip harvesting, there might be a possibility of harvesting coffee with microorganisms that naturally present in the production environment which use sugars in the pulp and mucilage and excrete organic acids and other metabolites that may affect the final sensory characteristics of the beverage. This result conforms with Getu (2009) work that indicated flavor is identified as an all-round good cup quality attribute which embraces positive values of aromatic attributes, acidity, and body Similarly, Anteneh (2011) stated poor harvesting practices such as stripping and collecting dropped fruits reduced the quality attributes like flavor.

CONCLUSIONS

The result revealed that the interaction of harvesting methods and drying surfaces were highly significant (P<0.001) difference for coffee bean size and dried coffee berry weight while significant (P<0.05) variation for primary defects, length of drying period. The main effect of harvesting methods and drying surfaces were highly significant on bean size, primary defect, secondary defect, length of the drying period, and dried coffee berry weight. Coffee beans harvested by selective harvesting and treated under different postharvest processing methods had 85%, except when coffee beans size dried on and above the minimum required bean size for export coffee as compared to strip harvesting beans in which all beans are recorded under rejected coffee due to many small beans (<76%).

The highest (16.51 gram) dried bean weight was verified in selective harvesting as well the lowest (13.59 gram) was in strip harvesting. Primary and secondary defects were highly significantly influenced by harvesting methods and drying surfaces. The highest length of drying period (41.67 days) was recorded from the interaction of wire mesh drying surfaces with selective harvesting method and the lowest (20.33 days) was recorded from the interaction of tin drying surfaces with strip harvesting method but statically at par with the interaction of plastic drying surfaces with strip harvesting method (20.67). The odor was significantly influenced due to the main effect of coffee harvesting methods and drying surfaces. The highest scale of the odor was recorded from selective harvesting and the lowest from strip harvesting. Acidity and flavor were affected by harvesting methods and selective harvesting produced a high raw quality of all attributes. The finding suggests that coffee physical quality could be better improved by the selective picking of red cherries. Moreover, drying coffee on bare ground highly reduced raw abnormal color and unpleasant odor.

ACKNOWLEDGMENTS

The authors thank the Ethiopian Coffee and Tea Authority for their technical support in coffee quality analysis.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

REFERENCES

Anteneh, T. 2011. Farm productivity and value chain analysis of coffee in Daro Lebu district, west Hararghe Zone of Oromia Regional State. M.Sc. Thesis presented to School of Graduate Studies of Haramaya University, Haramaya, Ethiopia. p.84

Asfaw, T. 2018. Evaluating the quality of coffee product on marketing performance of Ethiopian ommodity Exchange (ECX) Hawassa branch. *International Journal of Social Sciences Perspectives*. **2(1)**: 50-79. DOI: 10.33094/7.2017.2018.21.50.79

Barel, M., Jacquet, M. 1994. Coffee quality: its causes, appreciation and improvement. *Plant Research Development*, **1**: 5-13

Bee S., Brando CHJ, Brumen G, Carvalhaes N, Kolling-Speer I , Speer K, Suggi Liverani F, Texeira, AA, Thomaziello RA, Viani R, Vitzhum OG (2005). The Raw Bean. I n: Illy and Vianni (eds.) , Espresso Coffee The science of quality 2nd Edition. London, UK. Elsevier Academic Press, p. 87-178.

Belete, Y. 2014. Physical quality of Arabica coffee bean genotypes. In: Coffee Production, Variety and Trading ways to maximize Ethiopia's benefits, pp. 108–125. Girma A., Wube T, (eds.), Proceedings of 24thannual conference of the biological society of Ethiopia,

Berhanu, W. Ali, M., Essubalew, G. 2014. Impact of sun drying methods and layer thickness on the quality of highland *Arabica Coffee* varieties at Limmu, South Western Ethiopia. *J. Horticulture* **1**: 117. Doi:10.4172/2376-0354.1000117.

Berhanu, T. 2017. Ethiopian coffee sector strategy and future prospects, Coffee Tea and Spices Extension Director, ECTDMA, Addis Ababa, Ethiopia.

Boot, W.J. 2006. Coffee Processing Handbook: from the cherry to the green bean post harvesting coffee processing. Baarn, the Netherlands. pp. 173-192.

Boot, W.J. 2011. Ethiopian Coffee Buying Manual: Addis Ababa, Ethiopia. Practical Guidelines for Purchasing and Importing Ethiopian Specialty Coffee Beans. USAI D's Agribusiness and Trade Expansion Program. p.90

Chauhan, R., Hooda, M.S., Tanga, A.A. 2015. Coffee: The backbone of Ethiopian economy, A review. *International Journal of Economic Plants,* **2**(1):018-022,

Clifford, M.N. 1985. Chemical and physical aspects of green coffee and coffee products. In: Clifford MN, Willson KC(Eds.), Coffee botany, biochemistry, and production of beans and beverage. Croom Helm, London, pp. 305-374.

CSA (Central Statistical Agency). 2020. Agricultural Sample Survey, 2019/20 (2012E.C). Volume I: Report on area and production of major crops (Private peasant holdings, *Meher* season), Statistical Bulletin 587, Addis Ababa, 133 p.

Davids, K. 2001. Processing: Flavor and processing method in coffee review. p.1-4.

Desse, N. 2008. Mapping Quality profiles of Ethiopian Coffee by Origin. In:. Addis Ababa, Ethiopia: Girma A, Bayetta B, Tesfaye S, Endale T, Taye K (eds). Coffee Diversity and Knowledge, Ethiopian Institute of Agricultural Research,development. UNCTAD CNUCED, WTO OMC. Geneva. p.317-327

ECX (Ethiopia Commodity Exchange) (2010). ECX Coffee contracts. Addis Ababa, Ethiopia.

Endale, T., Behailu, W., Bayetta, B., Fabrice, D. 2008. Effects of genotypes and fruit maturity stage on caffeine and other biochemical constituents of *arabica* coffee. In: Proceedings of a National Work Shop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, EI AR, Addis Ababa, Ethiopia. pp. 169-172

FAO. 2006. Statistical Year book; Panama Profile. FAO, Rome.

FAO. 2010. Introduction to Coffee Drying. 'Good hygiene practices in the primary production of coffee. http://www.ico.org/projects/Good-Hygiene-Practices/

Getachew, E., Berhanu, T., Ali, M., Tesfaye, S., Yehenew, G. 2015. Influence of sun drying methods and layer thickness on quality of midland arabica coffee varieties at Gomma-II, Southe West Ethiopia. *Glob. J. Agric. Sci.* **3**(2):203-212.

Getu, B. 2009. Genotype x environment interaction of Arabica coffee (*Coffea arabica* L.) for bean biochemical composition and organoleptic quality characteristics. M.Sc. Thesis presented to School of Graduate Studies of Haramaya University, Haramaya, Ethiopia. P 124.

Gomez, K.A., Gomez, A.A. 1984. Statistical procedures for agricultural research 2nd ed, JSohn Willy and Sons. Inc., New York.

Hicks, P.A. 2002. Postharvest processing and Quality Assurance for Specialty/Organic Coffee Products. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

ICO (International Coffee Organization) 2015. Total Production by exporting countries

ITC (International Trade Center) 2011. Ethiopian Coffee Quality Improvement Project. Aid for Trade Global Review: Case Story. Geneva Switzerland. Available online at: http://www.intracen.org.

Killeen, J.T., Harper, G. 2016. Coffee in the 21st century. Will Climate Change and Increased Demand Lead to New Deforestation? . Conservation International, New York

Martin, S., Donzeles, S., Silva, M.L., Zanatta, J.N. and Cecon, P.R. 2009. Qualidade do café cereja descascado submetido a secagem continua eintermitente,em secador de camada fixa. Revista Brasileira de Armazenamento, Viçosa, Especial Café, p.30-36.

Mazzafera, P., Padilha-Purcino, R. 2004. Postharvest processing methods and alterations in coffee fruit. In: ASIC proceedings of 20thcolloquia coffee. Bangalore, India.

Mekonen, H. 2009. Influence of genotype, location and processing methods on the quality of coffee (*Coffea arabica* L.). M.Sc. Thesis presented to School of Graduate Studies of Hawassa University, Hawassa, and Ethiopia.105.

Mohammed-Sani, A., Wassu, M., Tesfaye, S. .2017. Evaluation of harvesting and postharvest processing method on raw quality attributes of green Arabica Coffee beans produced in Hararghe, eastern Ethiopia. *International Journal of Plant Breeding and Crop Science*, **4**(2): 187-196.

Negussie, M., Mitiku M, Agwada C(2009). Does Acquisition of Information and Knowledge Suffice? Lesson in Improving Coffee Quality through an innovative and integrated approach in Ethiopia. CABI Africa, Addis Ababa. pp: 1237-1241.

Olamcam, (2008). Report on Sustainability of Arabica coffee in the North West Region of Cameroon. An export coffee organization part of Olam International Agri Business, Singapore.

Pimenta-José C, Angélico, C.L., Chalfoun, S.M. 2018. Challengs in coffee quality: Cultural, chemical and microbiological aspects. *Ciência e Agrotecnologia*, **42(4)**:337-349,

Petit, S., Klevens, R.M., Morrison, M.A., Nadle, J., Gershman, K., Ray, S., Townes, J.M. 2007. Invasive methicillin resistant *Staphylococcus aureus* infections in the United States. *Jama,* **298(15)**, 1763-1771.

SAS. 2004. Statistical Analysis Software version 9.0, SAS Institute Inc. Cary, NC, USA.

Steiger, D.L., Nagai, C., Moore, P.H., Morden, C.W., Osgood, R.V., Ming, R. 2002. AFLP analysis of genetic diversity within and among Coffea *arabica* cultivars. *Theoretical and Applied Genetics,* **105**(2-3): 209-215.

Subedi RN (2010) .Comparative analysis of dry and wet processing of coffee with respect to quality in Kavre District, Nepal. M.Sc. Thesis submitted to Wagengen University. The Netherlands 43-51.

Tesfaye, K. 2006. Genetic Diversity of wild *Coffea arabica* populations in Ethiopia as a contribution to conservation and use planning ecology and development Series, 44.

Vaast, P., Bertrand, B., Perriot, J.J., Guyot, B., Génard, M. 2006. Fruit thinning and shade influence bean characteristics and beverage quality of *C. arabica* optimal conditions. *J. Sci. Food. Agric.* **86**:197-204.

Wintegens, J.N. 2004. Coffee: Growing, processing, sustainable production, a guide book for growers, processors, traders, and researchers, WILEY-VCH Verlag GmbH and Co. KGaA, Weinheium.

Yigzaw, D. 2014. Assessment of genetic diversity of Ethiopian Arabica coffee genotypes using morphological, biochemical and molecular markers. PhD Dissertation, University of the free state, Bloemfontein, South Africa.

(Received on 13.10.2021, Revised on 02.12.2021 and Accepted on 10.01.2022)