ASSESSMENT OF PHYSICAL PROPERTIES AND SENSORY QUALITIES OF ETHIOPIAN SPECIALTY WASHED GREEN COFFEE BEANS

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Abstract
Ethiopian coffee is popular globally by its specialty that depends on the growing region and variety. The mix-up of these specialty coffee varieties at the farm level, during harvesting and processing is not uncommon. For proper identification of the different specialty coffee varieties, there is the need to characterize them. In this regard, although some studies have been conducted on Ethiopian specialty coffee, little information are available on physical and sensory quality characterization of specialty coffee varieties. Hence, this study aimed to assess the physical and sensorial properties of sixteen specialty coffee varieties. The physical properties of washed green coffee beans were measured using digital caliper, analytical balance and measuring cylinder. Moreover, sensory quality was analyzed by a panel of professionals. Typically, the longest (10.44 mm) and the widest (7.01 mm) was variety Feyate and the thickest (4.55 mm) was Challa variety, while 74110 variety has the smallest length (8.32 mm). The shape & make value of variety Bultum was "fair good" whereas variety Feyate was "very good". Furthermore, the results of "shape and make" were significantly correlated with measured physical properties. Results indicated that most physical and sensory quality parameters have significant ($P \leq 0.05$) differences among the varieties. The physical and sensory properties of different varieties were influenced by variation in growing regions. The outcome of this study can be useful for variety identification of Ethiopian specialty coffee for different purposes such as procurement, coffee bean characterization and processing.

Keywords: Coffee varieties,coffee dimensions,physicalproperties, coffee Arabica, sensory attributes

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1. INTRODUCTION

Globally coffee grows in different agro-climatic conditions. Some of the most important coffee growing regions include Africa, South America, and India. Coffee Arabica, originated in Ethiopia, is known for its high quality beverage (Abdulmajid, 2014). Ethiopia is also one of the major producers of coffee in the world. Coffee production ranges from 329,518 to 574620 metric ton annually (ICO, 2018). The coffee industry in Ethiopia employs about 25% citizens directly and indirectly (Beshah, Kitaw, & Dejene, 2013). It is also one of the biggest foreign currency earner. As a result, it is an industry that has high national interest. The cup quality of coffee from Ethiopia is well accepted globally and it is currently exported to North America, Europe and Asia. Germany and Saudi Arabia remain the biggest importers for the last five years (ICO, 2018). However, there is some practice of mixing-up of varieties during planting, harvesting, and processing stages (Ameyu, 2016,2017; Tsegaye, Mohammed, & Getachew, 2014). As a result, this is affecting the uniqueness of Ethiopian specialty coffees. Moreover, this influences the inherent properties of each variety and compromises consumers' desire for a specific variety. Therefore, there is the need to differentiate these varieties at harvesting and processing stages.
The coffee physical and sensorial qualities depends on many factors that ranges from species choice, growing region, postharvest handling, processing and crop variety to the method of preparation of coffee for consumption (Afonso, Corrêa, Pinto, & Sampaio, 2003 ; Alves et al., 2017; Coradi,

Borém, Saath, & Marques, 2007; Lima et al., 2013; Scott, 2015). The criteria commonly used to evaluate the quality of coffee beans include bean size, color, shape, roast potential, processing method, crop year, cup quality, moisture content and the presence of defects (Belitz, Grosch, & Schieberle, 2009; Bicho, Lidon, Ramalho, & Leitão, 2013; Severa, Buchar, & Nedomová, 2013).
Sensory evaluation is one of the important methods for food product acceptability, development and improvement (Abdulmajid, 2014; Farah, Monteiro, Calado, Franca, & Trugo, 2006). On the other hand, coffee green beans quality can be characterized by both physical and sensory methods (Subedi, 2011).
Some literature is available on Ethiopian coffee varieties (Ameyu, 2016, 2017; Sualeh, Endris, & Mohammed, 2014 ; Tsegaye et al., 2014). Most of these studies focus on the impact of postharvest techniques and processing methods on cup quality. For instance, Sualeh et al. (2014) picked three varieties from JARC namely 744, 7440 and 74110. Then it dealt with processing methods and impact of roasting on physical quality attributes. Furthermore, Tsegaye et al. (2014) used two varieties from Limu Coffee Plantation Enterprise (LCPE) namely 744 and 74110 for assessment of the influence of sun drying method and layer thickness on the coffee cup quality. Moreover, Ameyu (2016) and Ameyu (2017) used H-622/98 inform MARC for physical quality analysis of roasted coffee beans.
In this context, for the best of the authors knowledge, the physical and sensory qualities of Ethiopian specialty coffee varieties have not been dealt yet. Consequently, it is important to characterize green coffee beans by studying the shape, size, volume, bulk and apparent densities, and sensory attributes of different varieties coffee green beans. Therefore, the main purpose of this study was to determine the correlation of some physical properties with sensory qualities of sixteen varieties of Ethiopia washed specialty green coffee beans.

2. MATERIALSAND METHODS

Materials

Sixteen Ethiopia specialty coffee varieties namely Feyate, Odicha, Angefa, Qoti, Arusa, Bultum, Machara-1, Mocha, 744, 741, 7487, 74110, Menesibu, Haru-1, Challa and Sende.were obtained from four agricultural research centers. These are Awada (6°3'N, 38°3'E, 1740 masl altitude,11-28 °C temperature and 1335 mm mean annual rainfall), Mechara (40°19.114 N, 08°35.589 E, 1760 masl altitude, 16 °C annual average temperature and 963 mm annual average rainfall), Jimma (7°40'9"N, 36°47'6"E, 1753 masl altitude, 9-28 °C temperature and 1561 mm annual rain fall) and Haru (7°40'9"N, 36°47'6"E, 1750 masl altitude, 18.9-26.8 °C and 1561 mm annual rain fall) that comprise five major coffee Arabica growing regions of the country (Fig. 1).

Experimental setup and design

In this study, the samples were collected from by different agricultural centers that are responsible for dissemination of these varieties to the respective growing regions of the country. Twelve kilograms of fully matured red cherry for the sixteen varieties were collected and processed to green beans at the respective centers (i.e., AARC, MARC, JARC and HARC) using wet processing method as described by Coradi et al. (2007) and Taveria et al. (2015). These samples were collected at peak harvesting time between October to November, 2016. The green coffee beans were then transported to Addis Ababa institute of Technology (AAiT) in a continuous chilled container with icebox at - 4 °C. At the AAiT School of Chemical & Bioengineering, green beans were stored in a refrigerator at 4 °C until the time of analysis. A randomized complete block design (RCBD) was employed with three separately treated replications for both dimension and sensory analyses.

Dimensions of washed coffee beans

Linear dimensions

The three linear dimensions; length (major), width (intermediate), and thickness (minor), of 30 green beans from each variety were measured using a digital caliper (Vernier Caliper, 150mm/6 inch 3 Buttons, China) as the method described by Olukunle and Akinnnuli (2012).

Geometric dimensions

The volume, cross-sectional, cross-sectional area, sphericity, shape index and coefficient of contact surface of washed green coffee beans were calculated according toMohsenin (1986), as:

Volume (V):

$$V = \frac{\pi}{6} LWT, mm^3 \quad (1)$$

Cross-sectionalarea (CSA):

$$CSA = \frac{\pi}{4} \frac{(L+W+T)^2}{3}, mm^2 \quad (2)$$

Sphericity (S):

$$S = 100 \frac{(LWT)^{0.333}}{L}, \% \quad (3)$$

ShapeIndex (SI):

$$SI = \frac{L}{\sqrt{(W*T)}} \quad (4)$$

Coefficientofcontactsurface (CCS):

$$CCS = \frac{FSA-TSA}{FSA} * 100 \quad (5)$$

Where: FSA(frontal surface area):

$$FSA = \frac{\pi}{4} * L * W, mm^2 \quad (6)$$

TSA (transverse surface area):

$$TSA = \frac{\pi}{4} * T * W, mm^2 \quad (7)$$

Where, L, W, and T are length, width and thickness, respectively.

Weight of washed green coffee beans

The weight of individual beans was determined by a digital balance (ER-120A, AND, Japan) with an accuracy of 0.0001 g. Ten beans were selected at random from washed coffee samples that are retained over 14 – inch screen. The test was repeated three times and averaged to obtain a single value for the weight (Pittia et al., 2007).

Bulk density

The bulk density of the coffee beans was measured and evaluated as the ratio between the weight and volume according to the method described by Pittia et al. (2007). The results of bulk density (equation 8) expressed as the mean value of three measurements.

$$Bulk\ Density\ (\rho) = \frac{weight\ of\ washed\ green\ coffee\ beans}{Bulk\ volume\ of\ beans\ in\ a\ measuring\ cylinder} \quad (8)$$

Apparent density

The apparent density (equation 9) of coffee beans were determined according to the method of Olukunle and Akinnnuli (2012). The weight and linear dimensions of ten randomly selected beans from each of the sixteen varieties were measured using a digital balance and a digital caliper, respectively. In this regard, triplicate measurements were taken to investigate the variance of the average values in the single coffee bean.

$$Bulk\ Density\ (\rho) = \frac{weight\ of\ washed\ green\ coffee\ beans}{Bulk\ volume\ of\ beans\ in\ a\ measuring\ cylinder} \quad (9)$$

Screen size and moisture content

Bean size distribution was carried out by means of rounded perforated plate called screen. The screen holes were specified in 1/64 inch, which means 14/64 of an inch diameter of the screen. The weight of each of the sixteen varieties of washed green coffee bean above screen size 14-inch was recorded as percentage. The screen size of the sixteen varieties of washed green coffee beans were determined according to the methods described by Oliveira, Corrêa, Reis, and de Oliveira (2015). However, moisture content of washed coffee beans was conducted using oven method (Method 979.12) at 105 0C for 16 h (AOAC, 2007).

Sensory quality of washed coffee beans

400 g from each of the sixteen varieties were stored in a refrigerator at 4 C and transported to Jimma Agricultural Research Center

laboratory for sensory analysis. Sensory analyses were carried out at Jimma Agricultural Centre Laboratory, Jimma, Ethiopia. Three professional taste panels were involved in determining sensory of washed coffee green beans according to the methods of Sualeh and Mekonnen (2015). Scores of the shape & make, color and odor for the sixteen varieties washed green coffee beans were given according to Table 1.

Experimental design and statistical Analysis

The data were statistically analyzed using JMP Pro for Windows (version 13.0.0 (64 bit), 2016, SAS Institute Inc., USA,). Analysis of variance (ANOVA) was performed on each physical and sensorial attributes of the sixteen varieties of washed green coffee beans. These results were expressed as mean ± SD. In addition, Tukey's test was used to separate means and differences at $P \leq 0.05$.

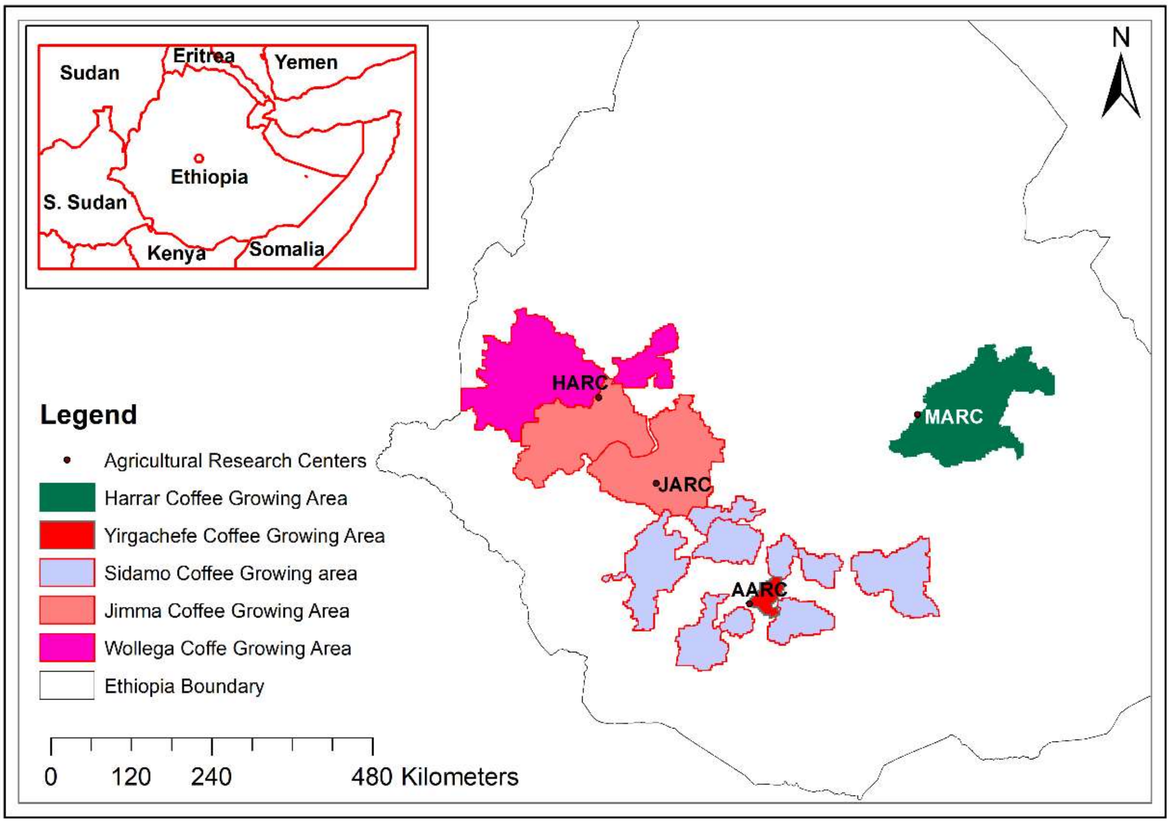

Fig. 1: Location map of the four centers with the major coffee growing regions of Ethiopia[1]

Table 1: The scale of washed green coffee beans used by sensory panel [Source: Sualeh and Mekonnen, 2015]

Scale	Attribute	Word anchor
1 – 15	Shape & Make	Small - Very Good
1 – 15	Color	White - Bluish
1 – 10	Odor	Strong - Clear

[1] AARC: Awada Agricultural Research Center; HARC: Haru Agricultural Research Center; MARC: Mechara Agricultural Research Center; JARC: Jimma Agricultural Research Center;

3. RESULTS AND DISCUSSIONS

Linear dimensions of washed green coffee beans

Size is one of the properties that are important in the design of handling system, grading and hulling of coffee beans (Chandrasekar & Viswanathan, 1999). Main dimensions of coffee beans are also considered in selecting, designing the suitable size of the screen perforations and determining the proper method of separation (El Fawal, Tawfik , & El Shal, 2009).

In this study, the linear dimensions of coffee varieties from Mechara were the smallest and that of Awada's were the largest as shown in Table 2. On the other hand, the average thickness of Haru varieties were the largest whereas Mechara's showed the smallest of all the centers. The largest dimension resulted in variety Feyate from Awada agricultural center while the smallest dimension was for variety Bultum from Mechara. The obtained results of dimensions were smaller than those of Yemeni coffee beans stated by Chandrasekar and Viswanathan (1999) of Indian & by Ismail, Anuar, and Shamsudin (2014). They were also higher than Nigerian Arabica coffee beans that observed by Olukunle and Akinnnuli (2012). These differences may be due to agro – ecological and varietal differences.

The frequency distribution curves for the mean values of the dimensions showed a trend approaching a normal distribution. The frequency distributions of linear dimensions (length, width and thickness) of washed green coffee beans were shown in Fig. 2. It showed that the highest frequency distributions of length (33.5 %), width (64.4 %), and thickness (48.1 %) are in the ranges 9 – 10 mm, 6 – 7 mm, and 4 – 5 mm, respectively. According to the mean comparison there were significance differences ($P \leq 0.05$) among the washed coffee green beans in terms of varieties length, width and thickness.

Table 2: Mean Values for Linear Dimensions of Ethiopian Specialty Green Coffee Beans

Center	Variety	Length	Width	Thickness
Awada	Feyate	10.44+ 0.66	7.01+0.49	4.13+0.38
	Odicha	9.49+0.99	6.52+0.38	3.81+0.28
	Angefa	10.12+0.80	6.43+0.45	4.00+0.27
	Qoti	10.01+0.71	6.72+0.53	4.15+0.52
Mechara	Arusa	9.12+1.00	6.17+0.45	3.74+0.36
	Bultum	8.57+0.75	5.60+0.48	3.88+0.50
	Mechara-1	8.71+0.73	5.91+0.39	3.67+0.30
	Mocha	8.72+0.74	5.67+0.43	3.79+0.38
Jimma	744	9.41+0.91	6.56+0.44	4.32+0.49
	741	8.89+0.66	6.20+0.46	4.04+0.33
	7487	9.56+0.84	6.73+0.48	4.46+0.34
	74110	8.32+0.63	6.33+0.39	4.11+0.39
Haru	Menesibu	9.70+1.07	6.60+0.46	4.15+0.39
	Haru-1	10.11+1.08	6.49+0.61	4.23+0.42
	Challa	9.98+0.62	6.47+0.59	4.55+0.56
	Sende	9.82+0.89	6.49+0.32	4.37+0.47

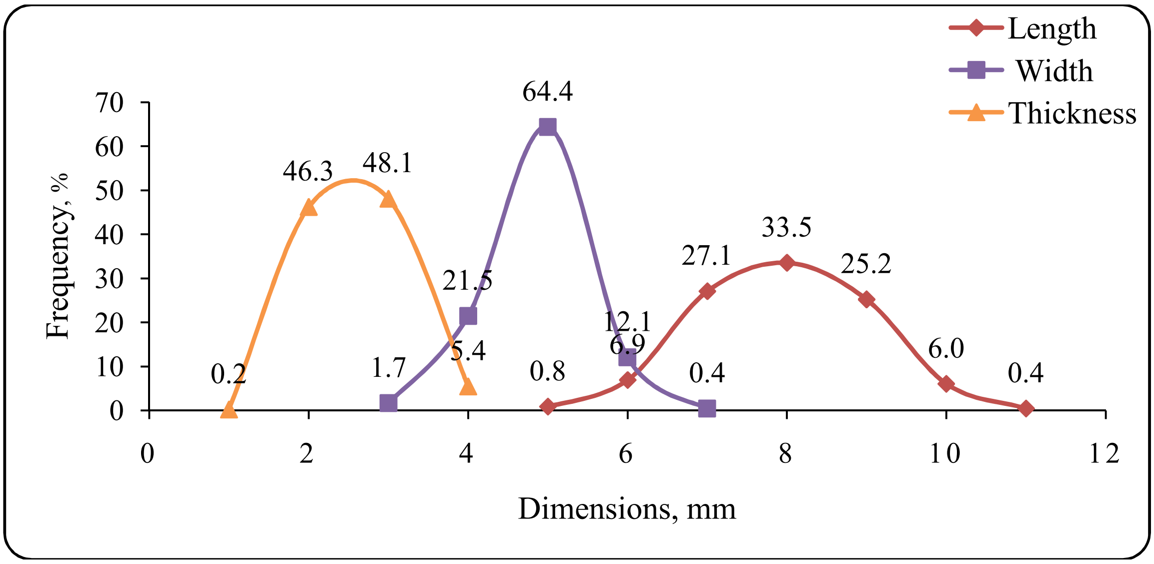

Fig. 2: Frequency distributions of linear dimensions washed coffee beans varieties

Geometric dimensions of washed coffee beans

According to Niveditha, Sridhar, and Balasubramanian (2013) the size, surface area and volume are essential in bulk handling and processing operations especially in heat and mass transfer. Coffee sizes are referred to as grades, because there is a general correlation between a bean's size and its quality. If all other factors are equal, however, a larger coffee bean will generally produce a higher quality brew than a smaller one (Scott, 2015). According to Chandrasekar and Viswanathan (1999) the mass, size and volume varied with the growing regions of Kenya for the Arabica coffee beans.

The results of volume, cross-sectional area (CSA), and sphericity (S) of the sixteen varieties of washed coffee beans from this study are depicted in Table 3. The values of geometric dimensions (volume, CSA, and S) ranged from 97.17 to 158.30 mm^3, 85.55 to 122.12 mm^2, and 63.11 to 72.10 % with average values of 128.8 mm^3, 103.71 mm^2 and 66.45 %, respectively for all varieties of washed coffee beans.

Volume

Volume plays an important role in the roasting process where roasting makes the bean expand (Ismail et al., 2014). According to Table 3, the minimum, maximum and mean values of green coffee bean volume are 97.13, 158.30 and 128.68 mm3, respectively. The smallest volume (97.13 mm3) obtained for Bultum variety from Mechara and the highest (158.30 mm3) for Feyate from Awada. The Mechara's varieties taken for this study have smaller volume than from the overall mean volume (128.68 mm3) whereas the Haru's varieties have larger values. This variation may be due to varietal and growing region difference.

Cross-sectional area (CSA)

Surface area in irregular shaped seeds plays an important role in determining the projected area of the seeds moving in turbulent air stream and thus useful in designing the seed cleaners, separators and conveyors (Vishwakarma, Shivhare, & Nanda, 2012). In this study, the minimum, maximum and mean values of CSA of the green bean are 85.55, 122.12 and 103.71 mm2, respectively. The average CSAs of Awada's (112.60 mm2) and Haru's (112.92 mm2) varieties were the highest whereas Mechara's (88.80 mm2) was the lowest. The smallest cross-sectional area (85.55 mm2) was obtained from variety Bultum of Mechara and the highest (122.12 mm2) was variety Feyate from Awada.

Sphericity

The sphericity closer to 100 % results in higher tendency to roll about any of the three axes (Niveditha et al., 2013). The average sphericity value of Awada varieties (64.45 %) was the lowest while Jimma varieties (72.10 %) was the highest. Out of the experimented varieties, the minimum percentage value of sphericity is 63.11 % for Awada variety (Angefa) whereas the maximum sphericity value is 72.10 % for Jimma variety (74110). As per a study by Ismail et al. (2014), the sphericity value (0.63) of Liberica coffee of Malaysia is smaller than the mean value of sphericity (0.66) for all varieties of the current study for the Arabica coffee of Ethiopia. This may be due to agro-ecological and varietal differences.

For the sixteen specialty coffee variety, the mean values of geometric dimensions were significantly different at ($P \leq 0.05$). Therefore, these results will help proper identification of the coffee beans at processing, marketing and beverage preparation stages.

Shape-index (SI)

Shape-index is used to evaluate the shape of the coffee green bean that is considered as oval when the shape index > 1.5 or spherical for shape index ≤ 1.5 (Abdel El-Elah, 2008). The obtained results of shape index and coefficient of contact surface of washed green coffee beans of each varieties are shown in Table 2. The maximum, minimum and average shape index of coffee varieties were 2.00, 1.63 and 1.86, respectively. According to definition by Abdel El-Elah (2008), the shape of all the coffee varieties were found to have an oval shape. The lowest shape-index (1.63) was found for variety 74110 from Jimma whereas the highest (2.00) for Angefa from Awada. The mean comparison showed that there were significant differences ($P \leq 0.05$) among the shape indices and coefficient of contact surfaces for most coffee varieties under study.

Coefficient of contact surface (CCS)

The coefficient of contact surface is very important parameter to evaluate the contact surface between the bean and surfaces such as cleaning, roasting and milling machines (Abdel El-Elah, 2008). The maximum, minimum and average CCS of coffee varieties were 60.24, 50.53 and 56.26 mm2 respectively (Table 3). The results of shape-index and coefficient of contact surface of all the sixteen varieties are significantly different from the results of Yemeni Arabica coffee by Abdel El-Elah (2008). This may be due to the varietal and agro – ecological differences.

Table 3: The volume, cross-sectional area (CSA), sphericity (S), shape index (SI) and coefficient of contact surface (CCS) of washed coffee beans

Center	Variety	Volume, mm^3	CSA, mm^2	S, %	Shape Index	CCS, %
Awada	Feyate	158.30^{a}±20.21	122.12^{a}±10.37	64.22^{e}±3.55	1.95^{ab}±0.16	60.24^{a}±4.67
	Odicha	123.93^{c-d}±22.19	103.13^{cd}±13.29	65.29^{c-e}±4.56	1.91^{a-c}±0.18	59.49^{a}±4.42
	Angefa	136.39^{bc}±19.41	110.70^{bc}±11.39	63.11^{e}±3.47	2.00^{a}±0.17	60.24^{a}±3.60
Mechara	Qoti	145.85^{ab}±20.08	114.43^{ab}±11.00	65.19^{c-e}±3.72	1.91^{a-c}±0.16	58.20^{ab}±6.95
	Arusa	110.16^{d-f}±19.27	95.11^{d-f}±13.06	65.29^{c-e}±4.13	1.90^{a-c}±0.18	58.54^{ab}±6.38
	Bultum	97.13^{f}±14.95	85.55^{f}±9.51	66.62^{b-e}±4.63	1.85^{b-d}±0.18	54.10^{b-d}±8.76
	Mechara-1	98.93^{ef}±12.39	87.82^{ef}±8.74	65.93^{b-e}±3.71	1.87^{a-d}±0.16	57.50^{a-c}±5.42
	Mocha	97.85^{f}±12.90	86.71^{ef}±8.79	65.63^{b-e}±3.88	1.89^{a-d}±0.16	56.11^{a-c}±6.59
Jimma	744	139.99^{bc}±22.45	108.21^{bc}±12.48	68.43^{bc}±3.92	1.77^{c-e}±0.15	53.84^{b-d}±5.28

Center	Variety	Volume, mm^3	CSA, mm^2	S, %	Shape Index	CCS, %
Haru	741	$116.30^{de}\pm14.74$	$95.88^{de}\pm8.88$	$68.15^{b-d}\pm3.56$	$1.78^{c-e}\pm0.14$	$54.31^{b-d}\pm5.07$
	7487	$150.68^{ab}\pm24.84$	$113.01^{a-c}\pm13.06$	$69.01^{ab}\pm4.29$	$1.75^{de}\pm0.15$	$53.01^{cd}\pm5.91$
	74110	$113.50^{d-f}\pm17.01$	$92.32^{ef}\pm9.11$	$72.10^{a}\pm3.14$	$1.63^{e}\pm0.11$	$50.53^{d}\pm3.87$
	Manasibu	$139.05^{bc}\pm23.84$	$109.75^{bc}\pm14.29$	$66.38^{b-e}\pm4.09$	$1.86^{a-d}\pm0.17$	$56.89^{a-c}\pm4.98$
	Haru1	$144.80^{ab}\pm21.44$	$113.97^{ab}\pm13.69$	$64.60^{de}\pm4.81$	$1.94^{ab}\pm0.21$	$57.66^{a-c}\pm6.54$
	Challa	$153.31^{ab}\pm22.66$	$115.62^{ab}\pm10.26$	$66.43^{b-e}\pm3.85$	$1.85^{b-d}\pm0.16$	$54.31^{b-d}\pm5.97$
	Sende	$146.53^{ab}\pm25.84$	$112.36^{a-c}\pm13.32$	$66.52^{b-e}\pm4.09$	$1.85^{b-d}\pm0.17$	$55.23^{a-d}\pm5.67$

$^{a-f}$All values are means (± SD) of triplicate determination. Means designated by different superscripts in a column are significantly different at ($P \leq 0.05$)

Physical parameters of washed green coffee beans

The physical properties can be used to determine the quality and to assist in machinery design, storage and handling of coffee beans (Ismail et al., 2014). Because of the irregular nature of the shape and sizes of agricultural products, coefficient of variation (CV) may be used to characterize the quality of dispersion to the measured parameters about their means (Eke, Asoegwu, & Nwandikom, 2007). The physical parameters (mass of bean, bulk density, true density, mass over 14" screen and moisture content) of the washed green beans were investigated and ranged from 0.11 to 0.19 g, 0.66 to 0.73 g/mL, 0.98 to 1.68 g/mL, 71.94 to 99.09 % and 9.77 to 13.10 % with average values of 0.15 g, 0.68 g/mL, 1.35g/mL, 92.82 % and 11.17 % respectively (Table 3).

Weight of washed green coffee beans

In this study, the minimum, maximum and mean values of weight of washed green coffee bean were 0.11, 0.19 and 0.15 g, respectively as shown in Table 4. The minimum weight (0.11 g) was for Mocha variety from Mechara research center whereas the maximum (0.19 g) for Sende variety from Haru. The mean weight of green bean of the different varieties was 0.15 g which is lower than 0.19 g of the previous study by Chandrasekar and Viswanathan (1999). Mean comparison showed that there are significant ($P \leq 0.05$) differences among coffee varieties in their weight. This may be due to the growing season, agro – ecological and varietal differences.

Bulk and apparent densities

Botanic, horticultural, processing, storage and handling factors influence the bulk density of green coffee beans (ISO, 1995). To choose a proper roast profile, information density is the most important factor a roaster needs (Wilson, 2018). Moreover, the bulk density is considered for determination of contacting capacity, designing hopper dimensions in cleaning and grading equipment (El Fawal et al., 2009). According to Table 4, the bulk density of washed green coffee beans (0.66 – 0.73 g/mL) is lower than that of soya bean (0.84 g/mL) (Mohsenin, 1986), Canavaliaensiformis (0.78 g/mL) (Eke et al., 2007) and African yam bean (0.74 – 0.76 g/mL)(Taser, Altuntas, & Ozgoz, 2005). The apparent density < 1 g/mL indicates that the Canavalia seeds are lighter than water and hence float (Niveditha et al., 2013).

In this study, the washed green coffee beans apparent densities were >1 g/mL as shown in Table 4 and this implies that these varieties have the ability to sink in water except for Mechara-1 with 0.98 g/mL. This data is useful for optimum usage of cleaning of coffee. The results of bulk density for most varieties were significantly different at $P \leq 0.05$ whereas the apparent densities were not significant for most varieties.

Weight Over 14 – inchscreen

Factors that determine coffee quality are pre- and post-harvest processing techniques, grading, packing and transporting (Sualeh & Mekonnen, 2015). According to Table 4, the average weight percent over 14-inch screen was lower (82.06 %) for Mechara varieties and higher (97.47 %) for Awada's. The minimum, maximum, and mean percent weights over 14-inch screen size were 71.94, 99.09 and 92.82 %, respectively as shown in Table 4. The lowest value of weight percent over 14-inch screen (71.94 %) was for variety Bultum from Mechara and the highest (99.09 %) for Feyate from Awada. The results of weight percent over 14-inch screen for most varieties were significantly different at $P \leq 0.05$. This may be due to varietal and growing region variation.

Moisture content

The level of moisture content is important for preservation of coffee quality because moisture levels more than 12 % favor the growth of molds and cause off flavors affecting the quality of coffee (Koskei, Patrick, & Simon, 2015). According to Table 4, the average results of moisture content were lower (10.21 %) for Haru varieties and higher (12.56 %) for Awada's. The minimum, maximum, and mean results of moisture content were 9.77, 13.01 and 11.17 %, respectively. The lowest moisture content (9.77 %) was for variety Challa from Haru and the highest (13.10 %) for Odicha from Awada. The results of moisture content for most varieties were significantly different at $P \leq 0.05$. This may be due to variation of processing at different centers.

Table 4: Weight of bean, bulk and apparent densities, mass over 14'' screen, and moisture content

Center	Variety	Weight of Bean, g	Bulk Density, g/mL	Apparent Density, g/mL	Weight Over 14" screen, %	Moisture content, wb %
Awada	Feyate	$0.18^{ab} \pm 0.03$	$0.68^{d-f} \pm 0.005$	$1.41^{a-c} \pm 0.22$	$99.09^{a} \pm 0.02$	$13.07^{a} \pm 0.21$
	Odicha	$0.16^{a-c} \pm 0.03$	$0.68^{de} \pm 0.002$	$1.26^{a-c} \pm 0.27$	$96.24^{e} \pm 0.08$	$13.10^{a} \pm 0.17$
	Angefa	$0.17^{a-c} \pm 0.01$	$0.68^{d} \pm 0.005$	$1.27^{a-c} \pm 0.02$	$96.88^{d} \pm 0.02$	$11.37^{b-e} \pm 0.31$
	Qoti	$0.16^{bc} \pm 0.02$	$0.68^{d} \pm 0.004$	$1.19^{a-c} \pm 0.12$	$97.67^{c} \pm 0.07$	$12.70^{ab} \pm 0.60$
Mechara	Arusa	$0.12^{de} \pm 0.02$	$0.67^{e-g} \pm 0.003$	$1.23^{a-c} \pm 0.11$	$87.11^{j} \pm 0.38$	$11.53^{b-d} \pm 0.40$
	Bultum	$0.12^{e} \pm 0.02$	$0.68^{d-f} \pm 0.003$	$1.08^{bc} \pm 0.20$	$71.94^{l} \pm 0.07$	$10.87^{c-g} \pm 0.06$
	Mechara-1	$0.12^{e} \pm 0.02$	$0.67^{fg} \pm 0.004$	$0.98^{c} \pm 0.05$	$88.28^{i} \pm 0.13$	$10.27^{d-g} \pm 0.25$
	Mocha	$0.11^{e} \pm 0.01$	$0.68^{cd} \pm 0.003$	$1.16^{a-c} \pm 0.12$	$80.92^{k} \pm 0.01$	$9.83^{fg} \pm 0.25$
Jimma	744	$0.16^{a-c} \pm 0.02$	$0.69^{c} \pm 0.003$	$1.59^{ab} \pm 0.21$	$97.68^{c} \pm 0.03$	$9.77^{g} \pm 0.15$
	741	$0.15^{cd} \pm 0.01$	$0.71^{b} \pm 0.003$	$1.29^{a-c} \pm 0.24$	$93.92^{g} \pm 0.02$	$11.53^{b-d} \pm 0.75$
	7487	$0.15^{bc} \pm 0.02$	$0.70^{b} \pm 0.003$	$1.42^{a-c} \pm 0.16$	$98.85^{a} \pm 0.02$	$11.60^{b-d} \pm 0.44$
	74110	$0.15^{cd} \pm 0.01$	$0.73^{a} \pm 0.003$	$1.51^{a-c} \pm 0.15$	$98.01^{b} \pm 0.01$	$12.23^{a-c} \pm 0.68$
Haru	Manasibu	$0.15^{bc} \pm 0.02$	$0.68^{d-f} \pm 0.003$	$1.46^{a-c} \pm 0.23$	$93.65^{g} \pm 0.02$	$11.20^{c-f} \pm 1.10$
	Haru1	$0.17^{a-c} \pm 0.02$	$0.66^{g} \pm 0.003$	$1.55^{a-c} \pm 0.13$	$91.62^{h} \pm 0.01$	$9.83^{fg} \pm 0.15$
	Challa	$0.18^{a-c} \pm 0.02$	$0.67^{e-g} \pm 0.003$	$1.54^{a-c} \pm 0.32$	$95.70^{f} \pm 0.02$	$9.77^{g} \pm 0.06$
	Sende	$0.19^{a} \pm 0.02$	$0.68^{d-f} \pm 0.003$	$1.68^{a} \pm 0.22$	$97.53^{c} \pm 0.00$	$10.03^{e-g} \pm 0.21$

$^{a-g}$ All values are means ± SD of triplicate determination. Means designated by different superscripts in a column are significantly different at ($P \leq 0.05$).

Table 5: Sensory qualities of washed green coffee beans

Center	Variety	Shape & Make	Color	Odor
Awada	Feyate	14.00^{a} ±1.00	14.00^{a} ±1.00	10.00^{a} ±0.00
	Odicha	12.67^{ab} ±0.58	13.33^{a} ±0.58	10.00^{a} ±0.00
	Angefa	13.00^{ab} ±1.00	13.00^{a} ±1.00	10.00^{a} ±0.00
	Qoti	13.33^{a} ±0.58	13.67^{a} ±0.58	10.00^{a} ±0.00
Mechara	Arusa	11.67^{ab} ±0.58	11.67^{a} ±0.58	10.00^{a} ±0.00
	Bultum	10.67^{b} ±1.15	11.67^{a} ±0.58	10.00^{a} ±0.00
	Mechara-1	11.67^{ab} ±0.58	11.67^{a} ±0.58	10.00^{a} ±0.00
	Mocha	12.00^{ab} ±1.00	12.00^{a} ±1.00	10.00^{a} ±0.00
Jimma	744	12.33^{ab} ±0.58	12.67^{a} ±0.58	10.00^{a} ±0.00
	741	12.33^{ab} ±0.58	13.00^{a} ±1.00	10.00^{a} ±0.00
	7487	12.67^{ab} ±0.58	12.67^{a} ±0.58	10.00^{a} ±0.00
	74110	13.33^{a} ±0.58	13.00^{a} ±1.00	10.00^{a} ±0.00
Haru	Menesibu	12.67^{ab} ±1.15	13.33^{a} ±1.15	10.00^{a} ±0.00
	Haru-1	13.00^{ab} ±1.00	13.33^{a} ±0.58	10.00^{a} ±0.00
	Challa	13.00^{ab} ±1.00	13.33^{a} ±1.15	10.00^{a} ±0.00
	Sende	12.33^{ab} ±0.58	13.33^{a} ±0.58	10.00^{a} ±0.00

$^{a\text{-}b}$All values are means ± SD of triplicate determination. Means designated by different superscripts in a column are significantly different at ($P \leq 0.05$).

Table 6: Partial correlation coefficients between each pair of variables for washed green coffee beans

	Volume	CSA	Sphericity	Shape Index	CCS	Weight of Bean	Bulk Density	Apparent Density	Weight over screen 14	Moisture content	Shape & Make	Color
Volume												
CSA	0.99**											
Sphericity	-0.08	-0.17										
Shape Index	0.08	0.17	-1.00**									
CCS	-0.05	0.06	-0.91**	0.90**								
Weight of Bean	0.38**	0.41**	-0.11	0.12	0.15							
Bulk Density	-0.13	-0.18	0.70**	-0.67**	-0.59**	-0.02						
Apparent Density	0.38**	0.36*	0.18	-0.18	-0.20	0.62**	0.12					
Weight over screen 14	0.36*	0.37*	0.15	-0.14	0.01	0.75**	0.30*	0.47**				
Moisture content	0.01	0.04	0.08	-0.06	0.14	0.1267	0.34*	-0.22	0.32*			
Shape & Make	0.38**	0.38**	0.02	-0.01	0.01	0.56**	0.12	0.30*	0.62**	0.28		
Color	0.25	0.25	0.05	-0.04	-0.01	0.57**	0.09	0.22	0.55**	0.27	0.52**	

** Highly significant ($P < 0.001$) and *Significant ($0.01 < P < 0.05$).

Sensory quality of washed green coffee beans

The shape & make indicates the bean boldness and uniformity in a sample. Shape & make is an important green bean physical characteristic of coffee that affects the roasting process and subsequently reduces cup quality. Moreover, both color and odor of green beans are another physical properties of coffee quality (Sualeh & Mekonnen, 2015).

In this study, the shape & make was evaluated as very good, good, fairly good, mixed, and small and weighted accordingly. Having uniform shape & make is an indicator of good green bean character because it affects the roasting process by having non uniform roasted beans that subsequently reduces cup quality (Sualeh & Mekonnen, 2015).

According to Table 5, the sensory quality (shape & make, color and odor)of washed green coffee beans range from 10.67 to 14.00, 11.67 to 14.00 and 9.33 to 10.00 with average values of 12.54, 12.85 and 9.88, respectively. The average shape & make value of Mechara varieties was in the range of "fair good" and "good" whereas the rest were in the range of "good" and "very good". The shape & make value of variety Bultum from Mechara was "fair good" whereas variety Feyate from Awada was "very good". Mean comparison showed that there are significant ($P \leq 0.05$) differences among coffee varieties in their shape & make. This may be due varietal and growing region differences. Mean comparison also showed no significant ($P \leq 0.05$) differences among coffee varieties in their color and odor. This may be due to the fact that the harvested red cherries were fully ripped, matured and well-processed into green beans using the washed process.

Multivariate Analysis

Pearson's product moment correlations between each pair of variables are shown in Table 6. These correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables. All values with superscripts ** ($P < 0.001$) and * ($0.01 < P < 0.05$ indicated statistically highly significant and significant, respectively. The following pairs of variables (sphericity vs CCS; sphericity vs shape index; sphericity vs bulk density; and CCS vs bulk density) were negatively correlated. The possible reason for the negative correlation of sphericity may be due to the oval shape result of the green coffee beans shown in the study. While on the contrary, weight of bean vs weight over screen 14; weight of bean vs apparent density; weight of bean vs shape & make; and shape index vs CCS were positively correlated.

4. CONCLUSIONS

From this study, the varietal difference were found to influence the physical and sensory quality of washed green coffee beans. Moreover, the physical parameters (weight of beans, bulk & apparent densities, weight over 14-inch screen and moisture content); linear dimensions (length, width and thickness); geometric dimensions (volume, CSA, sphericity, SI and CCS) and sensory qualities (shape & make, color, and odor) showed statistically significant correlation. For the sixteen Ethiopian specialty coffee varieties this study revealed that the physical and sensory quality indicators were statistically significant. These findings indicate that the study can be useful in terms of Ethiopian coffee varieties identification at harvesting, processing and marketing stages.

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