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Coffee Quality Profile Mapping of BenchMaji and Sheka Zones in Southwestern Ethiopia

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ደቡብ ምዕራብ ኢትዮጵያ የአረቢካ ቡና መገኛና ከፍተኛ የሆነ የቡና ብዝሃ-ሕይወት እንደሚገኝበት ይታወቃል፡፡ ጥራት የቡናን ዋጋ እንዲሁም በቡናው ምርት ላይ ያለውን ጠቀሜታ ይወስናል፡፡ በቤንችማጂና ሸካ ዞን አካባቢ ያለውን የቡና ጥራት ጣዕም ለመገምገምና ከአፈርና ከአካባቢያዊ የአየር ሁኔታ ጋር ያለውን ተዛምዶ ለማጥናት ይህ ሙከራ ተከናውኗል፡፡ ጥናቱ የተከናወነው ነስትድ (Nested) በተባለ ዲዛይን በሶስት ድግግሞሽ ነበር፡፡ ቀበሌዎቹ በወረዳ ውስጥ ነስትድ (Nested) ሆነው የተለያዩ ሶስት የቡና ማሳዎች በአንድ ቀበሌ ውስጥ ለድግግሞሽ ውለዋል፡፡ በአጠቃላይ 162 የቡና ናሙናዎች ተሰብስበው በጅማ የግብርና ምርምር ማዕከል የቡና ጥራት ባለሙያዎች የጥሬና የጣዕም ትንተና ተከናውኗል፡፡ በአብዛኛው የቡናው የጥሬና የጣዕም ባህሪያት በናሙናዎቹ መካከል ከፍተኛ የሆነ ተለያይነት እንዳለ ታውቋል፡፡ የየኪ ወረዳ ቡና የወንፊት መጠኑ ከፍተኛ (97.67) ሲሆን ሜኒትጎልዲያ ወረዳ አነስተኛ (95.33) መሆኑ ተለይቷል፡፡ የመቶ ቡና ፍሬ ክብደትን በሚመለከት የአንድራቻ ወረዳ ከፍተኛ (18.81 gm) እንዲሁም የሸኮ ወረዳ ዝቅተኛ ክብደት (16.20 gm) አሳይቷል፡፡ በጥሬ ቡና ግምገማ ውጤት ሜኒትሻሻ ወረዳ ከፍተኛ (36.53) ሲያገኝ ደቡብ ቤንች አነስተኛ (35.28) ውጤት አግኝቷል፡፡ ከፍተኛ (49.81) የቡና ጣዕም ውጤት በአንድራቻ ወረዳ ሲገኝ በየኪ ወረዳ አነስተኛ (43.33) የሆነ ውጤት ተገኝቷል፡፡ በአጠቃላይ የጥሬና ጣዕም ትንተና አንድራቻ ወረዳ ከፍተኛ ውጤት (86.23) ሲያስመዘግብ የኪ ወረዳ አነስተኛ (78.83) የሆነ ውጤት አግኝቷል፡፡ ከ85.00 በላይ የቡና ናሙናዎች 80.00 ከመቶ በላይ የሆነ አጠቃላይ ጥራትና ጣዕም ውጤት ያገኙት ስለሆነ ስፔሻሊቲ ቡና መሆን እንደሚችሉ ጥናቱ አሳይቷል፡፡ በአጠቃላይ በጥናት የቡና ጣዕም ባህሪያት ያገኙት ከተለያዩ የአፈር ከአካባቢው የአየር ጠባይ ጋር ከፍተኛ ቁርኝት እንዳላቸው ታውቋል፡፡ በተጨማሪ አዲስ የቡና ጣዕም የማር ቃና ያለው ቡና በቤንችማጂና ሸካ ዞን ተገኝቷል፡፡

Abstract

Southwestern part of Ethiopia is believed to be the origin of Arabica coffee which possesses the country to have the largest diversity in coffee genetic resources. Coffee quality determines the relative price as well as the usefulness of a given quantity of coffee. Therefore, the experiment was conducted to evaluate coffee quality of BenchMaji and Sheka zones (BMSZs) coffee producing areas and its correlation with soil and environmental variables. The experiment was laid out in Nested design with three replications. Kebeles were nested in each district and three farms in each Kebele were used as replication. One hundred sixty two coffee samples were collected and evaluated for green bean physical and cup quality traits by professional certified coffee tasters at the Jimma Agricultural Research Center, Ethiopia. Coffee physical quality (screen size, hundred bean weight, shape & make, color and total raw quality); cup quality attributes (aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor and overall cup quality) and total cup and total coffee quality were highly significant ($P \leq 0.01$). The Maximum mean value for screen size was recorded for Yeki (97.67) and the minimum was recorded for Menitgoldiya (95.33). Maximum mean value for hundred bean weight *was recorded for Anderacha (18.81gm) and the minimum (16.20 gm) was recorded for Sheko district. Similarly, the maximum total raw quality was recorded at Menitshasha (36.53) whereas the minimum was scored in SouthBench (35.28). Anderacha district had got maximum value (49.81) of total cup quality and minimum value (43.33) was achieved at Yeki district. Based on total coffee quality result Anderacha reveled maximum value (86.23) and minimum value 78.83 recorded at Yeki district. More than Eighty five percent (85%) evaluated coffee samples scored 80 points and above mean value of total coffee quality qualifying them as specialty coffee. Generally this study showed the presence of variation for coffee quality attributes and statistically significant correlations of coffee quality with soil and environmental factors. In addition, the results revealed that the existence of unique honey flavor.*

Keywords: Arabica coffee, District, Cup quality, Honey flavor and Raw quality.

Introduction

Coffee is one of the leading marketable commodities next to oil in world market. Commercial coffee production relies mainly on two related species, Arabica coffee (*Coffea arabica* L.) and Robusta coffee (*Coffea canephora* P.) (Lashermes *et al*., 2011). Arabica coffee contributes more than 65% of world's coffee supply (Anthony *et al.,* 2002; Vieira, 2006). It is originated from southwestern part of Ethiopia; the country hosts the largest diversity in coffee genetic resources (Mayne *et al*., 2002; Girma, 2003). Ethiopia produces large volumes of coffee every year, with 441,000 metric tons in 2018/19 alone (Abu and Rachel, 2020). Ethiopia is the 3rd largest Arabica coffee producer after Brazil and Colombia (ICO, 2015).

Vast agro-ecology and genetic variability in Ethiopia creates opportunity to have different distinct coffee quality characters. Even though Ethiopia is known for its coffee quality in world market for its unique flavor; it has not benefited from the enormous potential of its specialty coffees as expected. Presence of considerable variation in raw and cup quality characteristics among Arabica coffee due to genetic were reported (Yigzaw *et al*., 2008; Behailu *et al.,* 2008; Abeyot *et al*., 2011; Olika *et al*., 2011).

Profitability dominantly depends on the price of the coffee, which is determined by the coffee quality, as the consumer market increasingly demands a range of high quality flavor profiles. Coffee production is important to the Ethiopian economy (Abu and Teddy, 2015). For instance over millions of the farming households and about 25% of the total population of the country are dependent on coffee directly or indirectly deriving their livelihoods.

Good quality coffee production in specific areas characterized by their climatic conditions, clearly showed that climate is one of the important determining factors in coffee beverage quality (Silva *et al.,* 2005). Variable coffee growing environments in Ethiopia has a variety of characteristics sought in the international market. The country has favourable atmosphere for the production of different quality type that one cannot find elsewhere. So different unique flavour type like spicy for Sidama, flora for Yirgacheffe, mocha for Harerghe in the same way Limu, and Wollega coffee growing area are known with winy and fruity flavours respectively in the market.

Though Ethiopia has favourable conditions for production of quality Arabica coffee and coffee types with unique flavour and taste; the potential has been affected by climatic change, adulteration during processing out of the origin and also improper post-harvest processing techniques employed by some producers (Behailu *et al*., 2008; Berhanu *et al*., 2015). No effort has been made so far to determine quality profile of other coffee growing areas even if having distinct nature and large amount coffee production. For, instance in southwest Ethiopia coffee quality of BenchMaji and Sheka zones (BMSZs) is not well identified. Coffee production of BenchMaji zone represents about 12.6% of SNNPR and 4.4% of Ethiopia's total output (Dessalegn and Solomon, 2014). But coffee from south western parts especially BMSZs are mostly inferior quality having off flavored cups, bad appearance, many defective beans and so on (Nigussie *et al*., 2007). Furthermore, cup evaluation result shows unclean which are not free from musty, earthy and chemical taste which alters and influences the balance of acidity, body and flavor. This type of inferior quality comes from improper processing techniques. The need for proper processing of coffee and demarcating distinct coffee types by origin should therefore be taken seriously. Much work has not been done to quality profile mapping of BMSZs coffee with special emphasis on biochemical properties in addition to raw and cup quality assessment.

Though inherent coffee quality is influenced by genotype and agronomic practices, the main factors that influence coffee quality are postharvest and environmental variations. For instance BenchMaji coffee quality deteriorates due to critical problem of harvesting and post-harvest practices (Dessalegn and Solomon, 2014). The distinct coffee quality profile of BMSZs is not identified yet, though it was confirmed that low in quality. The absence of information on BMSZs coffee quality profile was major challenge that needs attention. So systematic studies associated with recommended coffee processing method for BMSZs is more important. Therefore, the present study was proposed to evaluate coffee quality characteristics and its correlation with some soil and environmental variables of BMSZs in southwest Ethiopia.

Materials and Methods

Description of the study area

The study was conducted in selected coffee producing districts of BenchMaji and Sheka zones in Southwest Ethiopia. BenchMaji lies between 5°33' and 7°21' N latitude and 34°38'and 36°14' E longitude with an elevation ranging from 800 to 2500 meters above sea level (masl). Sheka Zone lies between 7°24'and7°52' N latitude and 35°13'and35°35' E longitude with an altitudinal range of the areas in the Zone falls between 900 and 2700 masl.

Experimental design and sampling technique

The experiment was laid out in Nested design with three replications. Kebeles were nested in each district and three farms in each kebele were used as replication. Multi-stage sampling procedures were applied. In the first stage nine high coffee producing districts, seven from BenchMaji (NorthBench, SouthBench, Guraferda, Sheko, ShyBench, Menitshasha & Menitgoldiya) and two from Sheka (Yeki & Anderacha) zones, were selected using purposive sampling technique. In the second stage, six kebeles from each district were selected purposively based on potential of coffee production.

Experimental Procedures

Coffee sample preparation

From each selected coffee farm/field six kilograms of red mature coffee cherries were harvested during the main harvesting season. After coffee samples were collected based on farmers practices, unripe green berries, over mature cherries, dry cherries and other foreign materials were sorted out before pulping. At the spot of each kebele (farm) altitude, longitudinal and latitudinal positions were recorded using GPS. Soil samples were also collected from each coffee farm at 20 cm depth by excluding the top part using auger. Red fresh cherries were prepared in wet method of (pulping, fermentation and drying) coffee processing (Behailu *et al*., 2008). Wet parchment coffee samples were dried to the moisture content (MC) of 10.5-11.0% for all samples uniformly. Dry parchment coffee samples were hulled and hand polished to remove the parchment and silver skins from green coffee. Finally, 300 g of green coffee per sample were ready for physical and cup quality analysis.

Physical coffee quality analysis

The weight of randomly selected 100 beans weight (HBW) for each sample was measured using a sensitive balance. A green coffee bean sample weighing 100 g was used for a raw evaluation test before roasting. Bulk density of green coffee (BDGC), Bulk density of roasted coffee (BDRC), percent weight loss upon roast (%RWL) and percent volume change after roast (%RVC) were recorded using Eq.

1 to 4 respectively. Percent of beans above 14 screen size, shape & make (SM), color and odor of green coffee beans were evaluated based on the Coffee Quality Lab manual of Jimma Agricultural Research Center (JARC) using Table 1of a green coffee sample (Abrar and Negussie, 2015).

i. $BDGC = \left(\frac{WGC}{VGC}\right)$ ……………………………………….................(Eq. 1)

Where:-

BDGC= Bulk density of green coffee (gm/ml)
WGC = Weight of green bean coffee (gm)
VGC = Volume of green coffee (ml)

ii. $BDRC = \left(\frac{WRC}{VRC}\right)$ …………………………………………………(Eq. 2)

Where:-

BDRC= Bulk density of roasted coffee (gm/ml)
WRC = Weight of roasted coffee (gm)
VRC = Volume of roasted coffee (ml)

iii. $RWL = \left(\frac{WGC - WRC}{WGC}\right) \times 100$...………………………………….. (Eq. 3)

Where:-

RWL = Roast weight loss (%)
WGC = Weight of green coffee (gm)
WRC = Weight of roasted coffee (gm)

iv. $RVC = \left(\frac{VRC - VGC}{VGC}\right) \times 100$..……………………….................(Eq. 4)

Where:-

RVC = Roast volume change (%)
VRC = Volume of roasted coffee (ml)
VGC = Volume of green coffee (ml)

Roasting and brew preparation

The roaster machine with six cylinders (Probat BRZ6, welke, Von Gimborn Gmbh & Co. KG) were heated to 200°C and 100g green coffee beans per each sample were roasted for eight minutes (Abrar *et al.*, 2014). Roasted coffee samples were allowed to cool down rapidly by blowing cold air through it and ground to medium (0.5mm) size using electrical grinder (MahlKonig, Germany). Eight grams of powder coffee were added into each cup which has 180 ml of capacity (Schonwald, Germany) and five cups per sample were used. Boiled water (96°C) was poured into half volume of the cup and allowed to settle for approximately four minutes and the volatile aromatic quality and intensity parameters were recorded by sniffing. Then, the cups were filled to the full volume and left to settle floaters. Finally the surface of the beverage was skimmed off to remove foams and make ready for tasting by panelists.

Cup quality analysis

Coffee cup quality was evaluated at palatable temperature (60^{o}C) by a team of three certified Q-grader cuppers following the procedure of coffee quality lab manual of JARC (Abrar and Negussie, 2015). Data were collected on Aromatic intensity (AI), aromatic quality (AQ), acidity , astringency(AS), body, bitterness(BI), flavors, overall quality (OAQ) and also typicity/descriptor (Winy, fruity, flora, mocha, spicy and others). AI, AQ, AS and BI were evaluated 0 to 5 scales; while acidity, body, flavor and OAQ were assessed at 0 to 10 scales (Table 4). Then after panelists gave their free judgment of blind testing, the average point (of the panelists) was used for statistical analysis.

Moreover, to determine soils chemical properties, soil samples were air-dried in the laboratory, crushed and then sieved to 2 mm. The pH of soil sample was determined with 1:2.5 (Soil: Water suspension) and measured with a digital pH meter. Exchangeable acidity was extracted with 1M KCl. Exchangeable acidity was extracted with 1M KCl, followed by the quantification of Al and H by titration. Organic Carbon was determined by potassium dichromate oxidation method (Walkley and black, 1934). Total nitrogen (TN) was measured using the Kjeldahl method (Jackson, 1958). Available Phosphorus was determined by Bray II Method followed by quantification in a UV-vis spectrophotometer (Bray and Kurtz, 1945) at the laboratory of JARC.

Table 1: Evaluation scale for washed coffee raw quality attributes

Raw Value (40)					
Shape & Make (15)		**Color (15)**		**Odor (10)**	
Quality	**Pts**	**Quality**	**Pts**	**Quality**	**Pts**
Very Good	15	Bluish	15	Clean,	10
Good	12	Grayish	12	Fair Clean	8
Fair good	10	Greenish	10	Trace	6
Average	8	Coated	8	Light	4
Mixed	6	Faded	6	Moderate	2
Small	4	White	4	Strong	0

Source: Abrar and Negussie, 2015

Table 2: Evaluation scale for washed coffee cup quality attributes

Cup Value (60)									
Points to rated 0 to 5					Points to rated 0 to 10				
Aromatic Quality	Aromatic Intensity	Astringency	Bitterness	Points	Acidity	Body	Flavor	Overall cup Quality	Points
Excellent	V. strong	Nil	Nil	5	Pointed	Full	V. good	Excellent	10
V. good	Strong	V light	V light	4	M. pointed	M. full	Good	V. good	8
Good	Medium	Light	Light	3	Medium	Medium	Average	Good	6
Regular	Light	Medium	Medium	2	Light	Light	Fair	Regular	4
Bad	V light	Strong	Strong	1	Lacking	V. light	Bad	Bad	2
Nil	Nil	V. strong	V. strong	0	Nil	Nil	Nil	Unacceptable	0

Source: Abrar and Negussie, 2015

Data analysis

Analysis of variance was computed for each quality parameter using statistical analysis system software version 9.3 (SAS, 2011) in order to identify variations among raw and cup quality parameters. Parameters which showed significant differences among the treatments were compared using fisher's least significant differences (LSD) at 5% probability level. Besides, to see the relationship between different variables, Pearson correlation analysis was performed among coffee quality and environmental variables using IBM SPSS Statistic 20 programme (SPSS, 2011).

Results and Discussions

The coffee samples collected from fifty four Kebeles were evaluated for different quality attribute variation and the results presented in Table 3 to 5. Significant difference for physical and cup quality were achieved due to district variation. The effect of Kebele within district also showed significant difference on physical coffee quality and cup quality. Checking the sensory profile of coffee cup quality to ensure the consistent quality, sensory evaluation is certainly the most reliable way to assess the quality (Prodoliet, 2004). Correlation of coffee quality with and soil chemical properties and environmental variables are listed in Table 6 and 7.

Physical coffee quality

Analysis variance revealed that physical coffee quality attributes showed significant differences among districts ($P < 0.05$) except moisture content, odor, BDRC, % RWL and % RVC which showed non-significant differences (Table 3). The total percentage of coffee retained above screen size number 14 was significant ($P < 0.05$) due to district difference (Table 3). Yeki district scores higher (97.67) coffee screen size percentage (Table 4). The lower score (95.33) was achieved in Menitgoldiya district. Similarly, the parameter shape and make as well as color of raw coffee bean were significant ($P < 0.05$) due to district difference (Table 3). The highest shape and make mean value of 13.36 with more uniform appearance coffee was recorded for Menitshasha district (Table 4). Whereas the lower value was scored in SouthBench district without statically variation of shape and make score ranging from12.56 to 12.83 with the value. Similarly, thus, the highest result bluish to grayish color value achieved (13.28) for Anderacha district coffee without statistical different with Sheko, Guraferda, Menitshasha and Shybench districts (Table 4). The least color value was achieved for coffee sample collected from SouthBench district scoring mean value of 12.72. Coffee color profiles were influenced by environmental effect on coffee production area.

Total raw coffee quality was significant (*P* <0.05) due to the effect district variation (Table 3). Among districts the higher mean value (36.53) of total raw quality registered coffee samples collected from Menitshasha district without significant difference with Anderacha (36.42) and Sheko (36.08); whereas the lower total raw value (35.28) was recorded for SouthBench without statistical difference with coffee sample collected from Yeki, NorthBench, Menitgoldiya and Guraferda districts (Table 4). Coffee evaluated for BDGC significantly (*P* < 0.05) affected by district variation (Table 3). The higher value 0.722 BDGC was recorded in NorthBench and Menitshasha districts whereas the lower value 0.706 was scored for Yeki and SouthBench (Table 4). Similarly, highly significant (*P* <0.01) difference was observed among the districts for hundred bean weight and the highest (18.81gm) hundred bean weight value was recorded for coffee sample collected from Anderacha district (Table 4). Whereas the lowest (16.20gm) value was recorded for coffee samples collected from Sheko district. Even if there were no significant difference among the districts for % MC , odor, BDRC, % RWL and % RVC their values ranged 10.42 to 10.54% for % MC , 9.94 to10.00 for odor, 0.398 to 0.431 for BDRC, 12.21 to 13.44 for % RWL and54.37 to 56.50 for % RVC.

Regarding effect of Kebele within district, significant differences were observed (*P* <0.05) for coffee screen size, SM, color and total raw quality (Table 3). However, moisture content, odor, BDGC, BDRC, %RWL, %RVC and hundred beans weight did not show significant difference among kebeles within districts. Raw quality attributes values such as SM, color and odor of green coffee beans affected by pre and postharvest processing. If other factors are kept constant better raw quality coffee can be produced from all districts of the study area. Green coffee with low moisture contents tend to roast faster than those with high moisture content (Leroy *et al.,* 2006; ITC, 2002). The screen profile should be above the need to meet the export standards. This result indicates the coffee form the study area full fill the need of export coffee. Ethiopian export coffee shall have the minimum 85% by percentage of bean weight remaining on top of screen 14 size (ECX, 2015).

Structural make up of different kinds of coffee beans is known as shape and make. The finding of coffee shape and make in the study area varies from good to very good. Growing environment favor the production of coffee beans with good shape and make. An inherent quality attributes of coffee expressed due to important role of environment (Leory *et al.,* 2006). Uniform shape and make coffee bean were achieved, because of good selective harvesting method. Strip harvesting of immature, mature, small and big size beans together will produce mixed and less uniformity shape and make. Properly harvested and processed green coffee beans become free of bad smells (Olamcam, 2008). Similarly Endale (2008) reported that, better management in each stage starting from coffee harvesting until cupping will give better odor. Poor harvesting practices of different maturity stage reduces quality and increases uneven distribution of coffee bean size (Anteneh, 2011). Well processed coffee has an attractive bluish raw color. Proper harvesting and drying practices are crucial in maintaining typical inherent quality characteristics (Mohammedsani, 2015). The raw coffee color profile from the study area was grayish to bluish gray. This was because the coffee samples were fully matured red fresh cherry color used. It was reported that, red matured and appropriate harvesting will give the best coffee bean size (Bertrand *et al*., 2006; ITC 2002). Coffee beans from appropriate harvesting and drying methods had better quality scores (Berhanu *et al.,* 2015; Kassaye *et al.,* 2018). The results further confirmed that presence of quality profile diversity for different quality attributes of Arabica coffee in the southwestern Ethiopia.

Cup quality analysis

All cup quality attributes showed highly significant differences among the districts ($P<0.01$) (Table 3). Aromatic intensity was highly significant ($P<0.01$) due to the effect district variation. Among districts the highest mean value of aromatic intensity (4.14) was recorded for coffee prepared from Menitshasha district without significant difference with Shybench, Anderacha and NorthBench (Table 5); whereas the lowest aromatic intensity (3.61) was recorded from Sheko district. Menitshasha district score the higher mean value (4.39) of aromatic quality among districts without significant difference with NorthBench, Shybench and Anderacha (Table 5); whereas the lower (3.58) aromatic quality was recorded for coffee sample from Yeki district. Results of the study also showed highly significant variations (P<0.01) on coffee acidity due to district difference (Table 3). The highest value of acidity (8.39) was recorded for coffee sample collected from Anderacha district, while the lowest Acidity value (7.33) was recorded for Yeki district (Table 5).

Coffee samples tested for its astringency showed highly significant variations ($P<0.01$) among districts (Table 3). Coffee sample from Menitshasha had very nil astringent (4.56) without significant difference among North Bench (4.39) and Guraferda (4.31). The lower value (3.53) astringency was recorded for coffee from Yeki district without statistical difference with Sheko district (Table 5).Astringency is complex sensation accompanied by shrinking drawing of the skin or mucosal surface in the mouth. Similar to astringency bitterness is not considered as a desirable quality attribute. Bitterness showed highly significant variations ($P<0.01$) among districts (Table 3). Coffee samples collected from Menitshasha had higher value (4.50) very nil for bitterness without significant difference with NorthBench, Guraferda, SouthBench and Anderacha districts (Table 5). Moderate bitterness of lower value (3.58) was recorded for coffee sample collected from Yeki district without significant difference with Sheko district.

The mouth feel of beverage or its density property and viscosity of coffee brew during cup evaluation referred as body. Highly significant (*P*<0.01) difference of body among district were achieved (Table 3). Coffee samples collected from NorthBench and Anderacha had scores higher (8.06) value without significant difference SouthBench, Menitshasha, Menitgoldiya and Shybench districts (Table 5). But the lower body (7.33) was recorded in Yeki districts without statistical difference with Sheko and Guraferda districts. The flavors profile of coffee sample collected from BMSZs were highly significant (*P*<0.01) among districts (Table 3). Anderacha district showed the higher (8.25) flavor score (Table 7); while Yeki district had got lower (7.06) score without significant difference with Sheko (7.36). Honey sweet flavor coffee was achieved for most samples. In addition the flavor showed significant (*P*<0.05) difference by Kebele with in districts (Table 3). The results revealed the existence of variation of coffee quality attributes and unique flavor coffee to describe its typicity as honey flavor. The coffee samples showed that they were unique in most of coffee quality assessment scores among the districts. The findings of this research is similar with the results of Mekonen (2009), who reported significant variations in specialty attributes of Arabica coffee in Ethiopia. Overall cup quality of the coffee was evaluated based on the value of different quality attributes used to determine and evaluate quality potential of the coffee. The research result showed highly significant (*P*<0.01) variations in overall cup quality due to district variation (Table 3). The highest mean value (8.28) was registered coffee sample collected from Anderacha district whereas the lower value (7.19) was scored in Yeki district (Table 5).

The sum of cup quality attributes aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor and overall cup quality evaluated by cupper during evaluation is considered as total cup quality. The effect of district difference was highly and significantly (*P*<0.01) influenced total cup quality (Table 3). Among the districts Anderacha (49.81), NorthBench (49.78) and Menitshasha (49.08) score the higher value without significant difference. The lower total cup quality value (43.33) was achieved in district Yeki district (Table 5). Total coffee quality was evaluated based on the physical/raw and cup quality attributes of the coffee quality potential of the overall quality of coffee type. Total coffee quality was highly significant (*P*<0.01) due to district difference (Table 3). Among the districts Anderacha scores the higher value (86.23) of total coffee quality without significant difference with Menitshasha and NorthBench districts (Table 5). The lower total coffee quality was recorded for coffee sample collected from Yeki district (78.83). As far as the effects of kebeles within district is concerned, aromatic intensity, aromatic quality, acidity, flavor, overall coffee quality, total cup quality and total coffee quality showed significant differences (*P*<0.05) whereas astringency, bitterness and body showed non-significant differences.

The coffee physical and cup quality levels in this research work were within the ranges observed in other studies. BenchMaji and Sheka zones coffees were diverse in quality attributes havening new quality typicity/flavor. Ethiopia is known to produce extensive diversity of coffee having unique quality attributes likemocha, spicy, flora, winy and fruity flavours in market. Raw and cup quality variation among Arabica coffee accessions were reported in Ethiopia by different researches (Ky*et al.*, 2001; Silvarolla *et al.*, 2004). As the result indicted there is honey flavor which is not more known to Ethiopia. This described honey and floral flavor was especially for the coffee samples collected from highlands of study area. An inherent quality attributes of coffee expressed due to important role of environment (Leory *et al.*, 2006). If coffee from BMS zones prepared in a good way its quality is not as inferior in quality as reported by some authors (Nigussie *et al*., 2007). This is in line with previous findings that indicated Ethiopia as a center of origin and diversity of coffee (Steiger *et al.*, 2002). Emphasis should be given to post-harvest management of coffee to the southwestern part of the country. Specialty coffee buyers' looks for unique and notable products. Organoleptic quality evaluation of coffee could be considered more similar to the consumers' preference as it is the consumer at the end who finally judges beverage quality (Walyaro, 1983).

Table 3: Mean squares for raw and cup quality attributes of BenchMaji and Sheka Zone coffee

Variables	Factors		CV%
	Distinct	Kebele(District)	
Degree of Freedom	8	45	
Moisture content	0.03[ns]	0.05[ns]	2.53
Screen	12.22**	12.16**	0.98
Shape and make	1.15**	0.53*	4.32
Color	0.85**	0.52**	3.89
Odor	0.01[ns]	0.01[ns]	0.79
Raw total	3.22**	1.61**	2.18
Aromatic intensity	0.61**	0.14*	7.69
Aromatic quality	1.35**	0.30**	9.91
Acidity	1.99**	0.41**	5.59
Astringency	1.96**	0.16[ns]	11.50
Bitterness	1.73**	0.20[ns]	12.68
Body	0.90**	0.30[ns]	7.08
Flavor	2.34**	0.44*	6.82
Overall quality	1.91**	0.41**	5.63
Cup total	84.64**	11.29**	4.13
Total Quality	100.61**	14.41**	2.73
BDGC	0.0007*	0.0003[ns]	2.36
BDRC	0.0022[ns]	0.0011[ns]	9.30
%RWL	2.18[ns]	3.73[ns]	13.49
%RVC	8.36[ns]	10.95[ns]	5.46
HBW	14.31**	0.39[ns]	3.31

Bulk density of green coffee = BDGC, Bulk density of roasted coffee = BDRC, % Roast weight loss = WLR, % Roast volume change = RVC, Hundred bean weight = HBW,* = significantly, ** = highly significant

Table 4: Green bean physical characteristics of coffee samples in districts

Districts	Quality attributes					
	Sce	SM	Color	Raw	BDGC	HBW
North Bench	96.67^{b}	12.67^{c}	12.89^{bcd}	35.56^{cd}	0.722^{a}	17.68c
Guraferda	96.07^{bc}	12.78^{bc}	12.97^{abcd}	35.69^{bcd}	0.720^{ab}	16.78de
SouthBench	96.05^{bc}	12.56^{c}	12.72^{d}	35.28^{d}	0.706^{b}	16.40ef
Menitshasha	97.35^{a}	13.36^{a}	13.17^{ab}	36.53^{a}	0.722^{a}	18.19b
Menitgoldiya	95.33^{d}	12.92^{bc}	12.75^{d}	35.67^{bcd}	0.720^{a}	16.51ef
Shybench	95.83^{cd}	12.75^{c}	13.14^{abc}	35.89^{bc}	0.712^{ab}	17.68c
Sheko	97.33^{a}	12.83^{bc}	13.25^{a}	36.08^{ab}	0.714^{ab}	16.20f
Anderacha	95.83^{cd}	13.14^{ab}	13.28^{a}	36.42^{a}	0.717^{ab}	18.81a
Yeki	97.67^{a}	12.69^{c}	12.81^{cd}	35.50^{cd}	0.707^{b}	16.94d
Sd	2.15	0.64	0.60	1.01	0.02	1.02
LSD (5%)	0.62	0.37	0.33	0.52	0.011	0.38

Mean values followed by the same letter (s) within columns are not significantly different at P <0.05 level of significance, BDGC=Bulk density of green coffee, HBW=Hundred bean weight

Table 5: Cup quality characteristics of coffee samples in districts

Districts	Quality attributes								
	AI	AQ	AC	AS	BI	Body	FL	OCQ	TCQ	Total
North Bench	4.06^{ab}	4.25^{ab}	8.31^{a}	4.39^{ab}	4.44^{a}	8.06^{a}	8.08^{ab}	8.19^{a}	49.78^{a}	85.33^{a}
Guraferda	3.89^{bcd}	3.97^{cd}	7.75^{bc}	4.31^{abc}	4.28^{ab}	7.67^{bc}	7.50^{cd}	7.81^{bc}	47.17^{b}	82.86^{b}
SouthBench	3.82^{cd}	3.82^{de}	7.92^{b}	4.19^{bcd}	4.31^{ab}	7.75^{ab}	7.69^{cd}	7.81^{bc}	47.31^{b}	82.58^{b}
Menitshasha	4.14^{a}	4.39^{a}	7.97^{b}	4.56^{a}	4.50^{a}	7.89^{ab}	7.81^{bc}	7.83^{b}	49.08^{a}	85.61^{a}
Menitgoldiya	4.00^{abc}	4.03^{bcd}	7.78^{bc}	4.03^{cd}	4.08^{bc}	7.72^{ab}	7.56^{cd}	7.65^{bc}	46.84^{b}	82.51^{b}
ShyBench	4.11^{a}	4.22^{abc}	7.95^{b}	3.97^{de}	4.08^{bc}	7.81^{ab}	7.69^{cd}	7.81^{bc}	47.64^{b}	83.53^{b}
Sheko	3.61^{e}	3.67^{e}	7.56^{cd}	3.69^{ef}	3.81^{cd}	7.64^{bc}	7.36^{de}	7.53^{c}	44.86^{c}	80.94^{c}
Anderacha	4.06^{ab}	4.14^{abc}	8.39^{a}	4.22^{bcd}	4.42^{ab}	8.06^{a}	8.25^{a}	8.28^{a}	49.81^{a}	86.23^{a}
Yeki	3.72^{de}	3.58^{e}	7.33^{d}	3.53^{f}	3.58^{d}	7.33^{c}	7.06^{e}	7.19^{d}	43.33^{d}	78.83^{d}
Sd	0.36	0.51	0.59	0.54	0.57	0.58	0.65	0.58	3.15	3.54
LSD (5%)	0.20	0.26	0.29	0.31	0.35	0.36	0.35	0.29	1.29	1.50

Mean values followed by the same letter (s) within columns are not significantly different at P < 0.05 level of significance; AC = Acidity, AI = Aromatic intensity, AQ = Aromatic quality, AS= Astringency, BI= Bitterness, FL= Flavor, TCQ = Total cup quality and OCQ = Overall cup quality

Therefore the diversity observed in the collected coffee samples can be exploited for enhancement of beverage quality in Arabica coffee. The existence of variability in most of the coffee quality attributes also correspondences with the report by Nugroho (2016) who stated the existence of natural variation in relation to differences in coffee types, soil, altitude and rainfall conditions in different coffee producing areas. These coffee resources should therefore be properly prepared and handled to utilize them for improvement of sensory coffee quality which facilitate for the developing specialty coffee markets. Unique and special coffees are more attractive needed by specialty coffee buyers. Through these identified special coffee quality trait would possible benefit all actors along the coffee supply chain from the farm to the cup of BMSZs in particular and Ethiopia in general.

Correlations of coffee quality with soil and environment

Soil pH chemical property and coffee quality attributes such as: acidity, flavor, overall cup quality, total cup and total coffee quality exhibited negative and highly significant (*P*<0.01) correlations (Table 6). Significant negative correlations (*P*<0.05) were obtained between pH and quality attributes (AQ, BI and body). However, positive and significant (*P*<0.05) correlations were observed between overall cup quality and total nitrogen content of soil. The negative and significant correlation of soil PH with thee above attributes indicates that as the pH decreases the values of these quality attributes increases and vice-versa, this supported by the earlier work of (Enyan *et al.,* 2013) who reported acidity, bitterness, body, overall cup quality, total cup and total coffee quality attributes increase as the pH level decreases. High acidity coffee acquires premium prices. Clifford (1985) also stated that high acid coffee had a sharp, pleasing snappy flavor, which gave more intense aroma and better quality to the resultant beverage.

The result showed negative significant correlation of hundred bean weight with organic carbon. Soil exchangeable acidity chemical property showed positive significant correlation with color, acidity, flavor and overall cup quality. This implies that color, acidity, flavor and overall cup quality were found to improve with increased level of exchangeable acidity. Similarly, roast weight loss coffee quality attributes had positive and highly significant correlation with exchangeable acidity. Coffee produced form low level of exchangeable acidity loses more weight during roasting. This may be due to high amount of volatile compound during roast. Soils with a high % of organic material are more fertile (Mitchell, 1988) moreover; there is negative significant correlation soil acidity. Acidity level of the soil is also reported to produce a good quality coffee (Avelino *et al.,* 2005). The finding of this research related to the associations of soil N with coffee quality is in agreement with the report of Yara (2010).

Coffee growing altitude showed positive and significant (*P*<0.05) correlations with aromatic intensity, aromatic quality, acidity, body and flavor quality attributes for evaluated coffee samples (Table 7). Acidity, body, flavor and overall quality were highly and negatively significant (*P* >0.01) correlation with maximum temperature. In addition total cup quality and total raw quality were negatively significant (*P* >0.05) correlation with maximum temperature. Whereas any of the quality attributes did not show any significant correlation with minimum temperature. Annual rainfall was significant correlate with Color, Acidity, Body, flavor, overall quality and total coffee quality. Even though significant correlation for most quality attributes with environmental factor (maximum temperature, minimum temperature and rainfall) were not recorded, negative correlation with maximum-minimum temperature and positive correlation with rainfall were achieved (Table7). This indicates that the role environment in influencing the coffee quality of BenchMaji and Sheka coffee.

Coffee beverage quality is positively influenced at high altitude which increases positive quality attributes (Avelino *et al.,* 2005).Production of good quality coffee beans in specific areas characterized by their environmental conditions clearly showed that environment is important factor in determining quality of coffee beverage. According to De Castro & Marraccini (2006) environmental factors affect the physiology of coffee fruit development and ripening. Environmental factors affect coffee plant physiology and production may decrease as much as 80% in very dry years (Da Matta and Ramalho, 2006). At higher elevations ripening of coffee berries needs more time for complete bean filling (Vaast *et al.,* 2006). Higher altitude enhances to produce denser coffee beans and attractive stronger flavor. Coffee bean filled in longer duration with larger leaf area to fruit ratio is linked to superior cup quality (Silva *et al.,* 2005). Similarly, Van der Vossen (1985) stressed that high altitudes are critical for the successful production of high quality Arabica coffees in equatorial regions.

Table 6: Pearson correlation coefficients (r) between coffee quality and soil chemical properties

Coffee quality attributes	Soil chemical properties				
	pH	Phosphorus	Total Nitrogen	Organic Carbon	EXA
Moister content	-0.080	0.099	-0.107	0.028	0.090
Screen size >14	0.091	-0.039	-0.024	-0.020	0.118
Shape and Make	-0.101	-0.081	-0.134	-0.157	0.059
Color	-0.221	-0.262	0.041	-0.007	0.335*
Odor	-0.054	0.004	-0.022	0.122	0.040
Raw	-0.184	-0.191	-0.056	-0.088	0.221
Aromatic intensity	-0.197	-0.044	0.085	-0.102	-0.025
Aromatic quality	-0.279*	-0.092	0.046	-0.058	0.011
Acidity	-0.381**	-0.125	0.258	0.079	0.296*
Astringency	-0.232	-0.055	-0.036	-0.025	0.015
Bitterness	-0.271*	-0.182	0.063	-0.116	0.057
Body	-0.328*	-0.214	0.183	0.115	0.216
Flavor	-0.397**	-0.210	0.212	0.018	0.284*
Overall cup quality	-0.356**	-0.147	0.299*	0.077	0.327*
Total cup	-0.363**	-0.160	0.166	-0.014	0.192
Total quality	-0.374**	-0.194	0.135	-0.035	0.230
BDGC	-0.014	-0.087	0.076	-0.090	0.122
BDRC	0.094	-0.090	-0.032	-0.227	-0.099
%RWL	-0.113	0.118	-0.028	0.179	0.381**
%RVC	-0.063	0.073	0.044	0.189	-0.012
HBW	-0.095	-0.069	-0.166	-0.304*	0.005

*, ** = significant at P < 0.05 and 0.01, respectively; EXA = Exchangeable acidity, BDGC = Bulk density of green coffee, BDRC = Bulk density of roasted coffee, RWL = Roast weight loss, RVC = Roast volume change and HBW= Hundred bean weight.

Table 7: Pearson correlation coefficients (r) between coffee quality and environmental factors

Quality attributes	Environmental factors			
	Altitude(54)	Maximum (9)	Minimum (9)	Rainfall (9)
M.C.	-0.191	0.413	0.457	-0.188
Screen size >14	-0.090	0.564	0.321	-0.266
Shape and Make	-0.110	-0.095	0.053	0.393
Color	0.009	-0.348	-0.200	0.698*
Odor	0.211	-0.185	0.073	0.221
Raw	-0.046	-0.243	-0.068	0.602
Aromatic intensity	0.300*	-0.491	-0.222	0.258
Aromatic quality	0.333*	-0.521	-0.139	0.384
Acidity	0.277*	-0.886**	-0.558	0.702*
Astringency	0.018	-0.461	-0.127	0.356
Bitterness	0.129	-0.647	-0.281	0.519
Body	0.299*	-0.834**	-0.384	0.752*
Flavor	0.299*	-0.886**	-0.541	0.749*
Overall standard	0.232	-0.878**	-0.565	0.726*
Total cup	0.263	-0.767*	-0.392	0.616
Total quality	0.224	-0.747*	-0.372	0.673*
BDGC	0.192	-0.145	0.167	0.301
BDRC	-0.071	0.485	0.429	0.000
%RWL	0.008	-0.232	0.027	0.387
%RVC	0.097	-0.448	-0.181	0.560
HBW	0.047	-0.560	-0.578	0.474

*, ** = significant at P<0.05 and 0.01, respectively; BDGC = Bulk density of green coffee, BDRC = Bulk density of roasted coffee, RWL = Roast weight loss, RVC = Roast volume change and HBW= Hundred bean weight.

Conclusion

This study demonstrated that environmental factor and soil properties considerably influenced coffee quality in its production area. Considerable variation was observed for green bean physical and cup quality characteristics. Generally this study showed the presence of variation for coffee quality attributes and statistically significant correlations of coffee quality with soil and environmental factors. Among the organoleptic properties of the coffee assessed, acidity, overall quality flavor were most affected by soil properties. This high range and mean value for each quality trait of suggests that there is a great opportunity to select different coffee landraces having desirable quality attributes from these areas. Coffees with better cup quality were those collected from relatively higher altitude. This indicates production locality is a very important factor for the production of quality coffee. In general, the results interestingly revealed that the existence of variation of coffee quality attributes and unique flavor coffee described as honey flavor was identified from the study area. The existing result supports to map the coffee quality profile in the country to use the unique natural endowment of unexploited special coffee. So that it is essential mapping quality profile of Ethiopian coffee to discover new coffee flavor/typicity to remain competitive in the world market and to get niche market. To come up with more comprehensive conclusion the observed result of raw and cup quality attributes of BenchMaji and Sheka zones coffee should be confirmed using biochemical analysis.

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