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Research article

Biochemical composition of green and roasted coffee beans and their association with coffee quality from different districts of southwest Ethiopia

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ABSTRACT

Quality is a key criteria that can help producers win the global coffee market. Coffee quality can be expressed by physical, organoleptic as well as biochemical compositions. To determine biochemical compositions and antioxidant activity in green and roasted coffee and their correlation with cup quality samples were collected from nine districts of BenchMaji and Sheka zones. Significant variation in trigonelline, chlorogenic acids and caffeine content were observed among coffee samples. The result on dry matter basis range of trigonelline, chlorogenic acids and caffeine varied from 0.80 to 1.08 g/100g, 2.80–5.42 g/100g and 0.85–1.73 g/100g of green coffee, respectively. Antioxidant activity of green and roasted coffee showed highly significant differences across districts. Due to roasting, trigonelline, chlorogenic acids and antioxidant activity were lower in roasted coffee as compare to green coffee. Correlations between cup quality and some chemical composition of coffee vividly showed that the biochemical content of beans can significantly influence coffee quality. Biochemical compositions can be used in predicting the quality of coffee and has special importance in determining the quality of coffee diversity in the BenchMaji and Sheka zones.

1. Introduction

Coffee is one of the most economically important agricultural commodities worldwide (Jeszka-Skowron et al., 2015). The global coffee production is dominated by Arabica coffee (*Coffea arabica L.*) with a share of 64.5% (ICO, 2017). Arabica coffee is native to Southwestern Ethiopia and continues to serve as the main source of export earnings in the national economy, contributing decisively to the country's foreign exchange (Taye et al., 2011). Coffee is still the leading export commodity, contributing about 25% of commodity export revenues (~5% GDP) of Ethiopia (USDA-FAS , 2018). Moreover, coffee production is a vital business and wealth creation opportunity that contributes to poverty reduction in major coffee producing areas of Ethiopia (Abu, 2015). The country possesses a diverse genetic base and other natural factors that favor coffee productivity and quality.

Coffee quality is one of the key criteria that can help producers win global coffee market. More importantly, quality determines the relative price of coffee as frequently observed in the current world market, where supply exceeds the demand. Overall, coffee quality attributes and biochemical composition vary with genetic variation, environmental gradients, agricultural practices and postharvest processing techniques (Yigzaw et al., 2008). The genetic makeup of coffee and growing environmental conditions activate genes responsible for aroma precursors expressed during the roasting process (Yigzaw et al., 2007). Though quality is an inherent factor, the interaction between environment and genetic diversity can play the major roles in determining the physical, organoleptic and biochemical compositions of coffee beans (Mohammed et al., 2018).

Coffee is consumed for its stimulating and refreshing effects, which is influenced by a complex mixture of biochemical constituents. Green coffee biochemical composition primarily depends on genetic variation and bean maturation (Yigzaw et al., 2008). Moreover, most compounds related to the aroma of coffee are produced by partial destruction of the green bean during roasting through the process of pyrolysis, degradation and Maillard reaction. More than 950 compounds have been identified after roasting (Yeretzian et al., 2003) the amount and types of compounds reported being dependent on location, roasting degree and analytical methods used.

Caffeine (CAF), chlorogenic acids (CGA), sucrose and trigonelline (TRG) are known biochemical compounds of coffee which have been

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used for characterization of coffee species (Ky et al., 2001). Considerable variation of CAF, CGA, sucrose and TRG contents were observed in Arabica coffee (Silvarolla et al., 2004). These biochemical components of coffee are aroma precursors. Accordingly, correlations between coffee cup quality and some chemical attributes may be used as additional tools for evaluation of coffee quality (Farah et al., 2006).

CAF is an alkaloid compound responsible for bitterness of the coffee brew (Farah et al., 2006). During coffee roasting CAF is remained chemically stable except for minute reduction (Hečimovič et al., 2011). Similarly, TRG is an alkaloid contributing to the aroma of the brew and is a precursor for the formation of different classes of volatile compounds during roasting (Flament, 2001). It is also known to contribute to the formation of appreciated flavor products (Ky et al., 2001). Moreover, CGA is a phenolic compound responsible for coffee pigmentation, astringency, aroma formation and acidity to coffee brew (Farah et al., 2006). They are precursors of phenols that may confer unpleasant sensory notes (undesirable flavor) that are formed during roasting (Trugo, 2003). They also play an important role in the formation of roasted coffee flavor and have a marked influence in determining coffee cup quality (Farah et al., 2005).

Antioxidants are organic molecules and powerful substances preventing the oxidation of other molecules in our body. Coffee shows the highest antioxidant activity (AA) and has been reported to be the major and natural source of antioxidants (Ingvild et al., 2010). Antioxidants are essential for a number of bioactivities in human body. Coffee has 0.15–0.30 mg/g total antioxidant content (Yashin et al., 2009). CGA are the most prevalent phenolic compound content of coffee (Clifford, 2000).

Several studies were conducted to assess coffee quality performance throughout different regions of Ethiopia (Yigzaw et al., 2008; Abiyot et al., 2011; Kassaye et al., 2017; Mohammed et al., 2018). However, except for some information on coffee biochemical composition (Abiyot et al., 2011; Mohammed et al., 2018), there is no comprehensive research work on biochemical composition and antioxidant activity of coffee from BenchMaji and Sheka (BMS) zones in southwest Ethiopia. BMS are among higher coffee producer zones in southwest Ethiopia that contribute huge amounts of coffee for export to fetch foreign exchange to the country. Regardless of the huge genetic diversity that Ethiopia has, it is a pity that there is no comprehensive study to assess the biochemical composition of coffee from different growing regions with special emphasis given to quality attributes. Therefore, the absence of information on the biochemical composition and its correlation with coffee quality need immediate attention. Nowadays there is a lack of information regarding research done to quantify the qualitative correlation of coffee cup quality attributes and biochemical composition of green and roasted coffee beans. Thus, the present study aimed to determine the biochemical content and antioxidant activity of green and roasted coffee beans from BMS zones, and their correlation with coffee cup quality.

2. Material and methods

2.1. Description of the study area

The study was conducted on coffee samples collected from nine coffee producing districts of BenchMaji and Sheka zones of Southwest Ethiopia. BMS zones belong to the Southern Nations, Nationalities, and Peoples' (SNNP) region of 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 m above sea level (masl). It receives on average of 400–2000 mm rainfall per year. Sheka Zone lies between 7°24′ and 7°52′ N and 35°13′ and 35°35′ E with an altitudinal range of 900–2700 masl and it receives rainfall ranging from 1800 to 2200 mm per annum.

2.2. Experimental design

The experiment was laid out in Nested design with three replications. Seven districts from BenchMaji and two districts from Sheka zones were selected using a purposive sampling technique based on coffee production potential. Six higher coffee producer kebeles were selected from each district to collect representative samples. Six Kebeles were nested in each district and three representative farms in each kebele were used as replications. The investigations were carried out on 54 coffee samples collected from 9 districts of BenchMaji and Sheka zones.

2.3. Methods of coffee sample preparation

Six kilograms of red ripe coffee cherries were harvested from each randomly selected coffee farms during the peak harvesting season. Coffee samples were collected following farmers' practices regardless of coffee type (local/improved), age, shade tree type and level in bulk harvesting 10–20 years old coffee tree age. Red fresh cherries were prepared by excluding overripe, immature and dire cherries if any exist. Then red fresh cherries were wet processed by pulping using single disc hand pulpier. Subsequently, the fresh parchment coffee was fermented, soaked and washed. The washed parchment coffee was uniformly dried to the moisture level of 10.5–11.0%. Finally, dried parchment coffee samples were mechanically hulled and cleaned. Two hundred gram (g) clean undamaged coffee bean was prepared from each treatment for biochemical, AA and cup quality analysis.

Each coffee sample/treatment was subdivided into two for green and roasted bean analysis. Hundred grams of coffee beans per sample were ground to a fine powder size (<0.5mm) using green coffee grinder for analysis of green biochemical and AA. The other 100 g green coffee beans were roasted at 200 °C heated coffee roaster machines (Probat BRZ6, Germany) to medium level for 8 min. After air-cooling, each roasted coffee sample was ground into medium (<0.5mm) using electrical coffee grinder (Mahlkoing, Germany). The roasted ground coffee sample was used for cup quality evaluation, biochemical and AA analysis.

2.4. Cup quality analysis

Cup quality evaluation was done at Jimma Agricultural Research Center (JARC) under Ethiopian Institute of Agricultural Research (EIAR). Coffee samples were medium roasted and medium ground. Hot beverage was prepared by brewing 8 g roasted and ground coffee in 180 mL of hot water (95 °C). At palatable temperature of about 60°c cup evaluation was done following the Coffee Quality Lab manual procedure of JARC (Abrar and Negussie, 2015). Eight cup evaluation criteria were used. Aromatic intensity (AI), aromatic quality (AQ), astringency (AS) and bitterness (BI) were evaluated on 0 to 5 scales. Acidity (AC), body, flavor and overall cup quality (OCQ) were assessed on 0 to 10 scales. Cup evaluation was done by a panel of 3 experienced certified Q-grade cuppers (Abrar and Negussie, 2015).

2.5. Moisture content analysis

Moisture content of coffee samples was determined according to procedure suggested by AOAC (2000). About two grams (W_1) of the green coffee powder was weighed on a dish. The samples were dried in an oven set at 136 °C for one hour, cooled and reweighed (W_2). The loss in weight was calculated as the moisture loss and the value was expressed in percentage. The moisture content levels were used to obtain the dry matter content of the green coffee samples. The percentage dry matter content was calculated according to Eq. (1) (AOAC, 2000).

$$\%\ Dry\ matter = \frac{W_2}{W_1} \times 100 \quad (1)$$

2.6. Extraction of caffeine, trigonelline and chlorogenic acids

CAF, CGA and TRG extraction were done following the method adapted from Vignoli et al. (2014) with some modifications. About 0.5 g finely ground coffee powder was accurately weighed into a 50 mL

Erlenmeyer flask. 50 mL of heated (95 °C) distilled water was added and stirred for 20 min on hot plate. Then the extract was filtered using No. 4 What-man filter paper and subsequently filtered through 0.22 μm pore size and 10μL specimen was injected into on the High performance liquid chromatography (HPLC) (Agilent 1260 Infinity, Germany).

2.7. Determination of trigonelline, chlorogenic acids and caffeine

Simultaneous determination of TRG, CGA and CAF was done using the HPLC system consisting of Discovery C_{18} column with Isocratic flow of 0.7 mL/min methodology adapted from Vignoli et al. (2014) with some modification. The column used was a size of 4.6 × 250 mm 5 μm particle (Waters, Taunton, USA). Elute compounds with gradients containing 5 % acetic acid (A) and aceto-nitrile (B) were as follows:- 0–4 min: 4 % B; 4–8 min: 10 % B; 8–12 min: 90 % B; 12–15 min: 0 % B; and 15–17 min: 4 % B, at a flow rate of 0.7 mL/min. Three minute post run was used. TRG and CAF were detected at 272 nm, while CGA was detected at 320 nm. Calibration curves of CAF, CGA and TRG standards using triplicate measurements were used for quantification of those compounds. TRG and CAF were evaluated from 10, 20, 40, 50, 100 and 200 μg/mL, whereas CGA was evaluated over the range 10, 20, 100, 200 and 500 μg/mL. CAF, TRG and CGA were identified by comparing the retention times of CAF standard (99 %) (Fischer Scientific), TRG standard (Sigma Aldrich) and CGA standard (Acros organics) and their concentrations calculated from peak areas using calibration equations. Calibration curves were made using the standard concentration and area of sample subsequently used to calculate the composition of respective biochemical component using the area generated after a retention time (Gichimu et al., 2014).

2.8. Extraction and determination of antioxidant activity

Samples were extracted following the method described by Budryn and Nebesny (2008). One gram powder coffee was mixed with 10 mL methanol (99.0 %) from each green and roasted coffee. The mixture was homogenized for 60 s in a homogenizer (PLTYRON®2500E, Switzerland) and kept in a water-bath at 20 °C for 60 min, followed by filtration using Whatman No. 1 filter paper. The filtered extract was used for determination of antioxidant capacity. Antioxidant capacity was determined using free radical scavenging assay or DPPH (2, 2-diphenyl-1-picrylhydrazyl) assay as per the methodology developed by Hemalatha et al. (2010) with some modification. Then 200, 400, 600, 800, 1000 μL of extracted samples were added into each test tube and the volume was made up to 1.0 mL with the solvent (methanol). Next 2 mL of 0.1 mM DPPH was added to all the sample extracts and test tubes were shaken well and incubated at room temperature in the dark for 30 min. Decrease in the absorbance of the extracted solution was then measured at 517 nm (UV-Vis spectrophotometer, T80, China). All measurements were performed in triplicate and the mean was taken. Percentage of radical scavenging activity was calculated from absorbance values of samples and control sample using Eq. (2) (Melkayo et al., 2016).

$$Rsa\ \% = \left(\frac{Ac - At/As}{Ac}\right) * 100 \quad (2)$$

where:

Rsa = Radical scavenging activity
Ac = Absorbance of control (absorbance of DDPH (1.67)
At = Absorbance of test solution
As = Absorbance of standard Solution (absorbance of ascorbic acid (1.53))

2.9. Statistical analysis

Analysis of variance was computed for each biochemical contents in order to identify variation among coffee samples collected from different areas of BMS zones. Statistical Analysis Software Version 9.3 (SAS, 2014) was employed for analysis of variance using nested design. Differences between samples were compared using Fisher's Least Significance Difference (LSD) test at < 5 % probability level. Computer programme IBM SPSS Statistic 20 was used to perform Pearson correlation analysis among coffee cup quality, biochemical content and antioxidant activities.

3. Results

3.1. Roasting effect on biochemical content and antioxidant activity of coffee

The green and roasted coffee samples of BenchMaji and Sheka zones were evaluated for biochemical content and antioxidant activity. The analysis of variance revealed the existence of highly significant ($P < 0.01$) variation among biochemical constituents of both green and roasted coffee collected from BMS zones. Coffee roasting significantly ($P < 0.05$) decreased the TRG, CGA and AA of coffee beans (Table 1). As a result TRG, CGA and AA were higher in green coffee as compare to roasted coffee. The mean of CGA content in green coffee was 4.22 g/100g whereas due to roasting the content decreased to 1.94 g/100g resulting in a 54.0 % decrease of content. Likewise the TRG and AA content in green coffee decreased significantly (7.69 and 15.33 % respectively) because of roasting. However, the extent of loss was relatively less in TRG and AA as compared with CGA. The change in the caffeine content of coffee after roasting was not statistically significant and low percentage of alteration (2.52 %). The maximum loss in biochemical content of coffee was manifested in terms of percentage of CGA content of coffee.

3.2. Biochemical content and antioxidant activity of green coffee

The results for the biochemical content and antioxidant activity of green coffee for each district of the BMS zones are shown in Table 2. There was a significant difference ($P < 0.01$) in TRG content in tested coffee samples collected from BMS zones. The highest TRG mean value (1.00 g/100g) was recorded in coffee samples collected from Guraferda district (Table 2). While Anderacha district scores lower (0.86 g/100g) content of TRG. Higher amount (1.08 g/100g) of TRG content was at Dangela kebele in Guraferda district whereas the lower amount (0.80 g/100g) were recorded in Tugri kebele in Anderacha district and Kubito kebele in Yeki district (Table 3).

CGA content of green coffee bean showed highly significant ($P < 0.01$) variation among districts of the study area (Table 2). The highest mean value (4.45 g/100g) was achieved in coffee samples collected from Sheko district whereas the lowest value (3.69 g/100g) was attained in coffee from SouthBench district (Table 2). At kebele level, Getiba in Anderacha district had the highest chlorogenic acids (5.42 g/100g) while Yokichichi within the same district revealed the lowest (2.80 g/100g) amount of CGA (Table 3).

Significant differences ($P < 0.01$) were recorded for caffeine contents coffee samples from different districts. Green coffee from Guraferda district had the highest (1.52 g/100g) CAF content (Table 2) whereas the lowest (1.05 g/100g) CAF contenting coffee was found from Menitgoldiya district. At the lowest administrative level, Kebele, the highest amount of CAF (1.73 g/100g) was recorded from coffee sample collected from Philiya in Guraferda district. On the other hand, Tebenjayazhi in NorthBench district had the lowest (0.85 g/100g) amount of caffeine content (Table 3).

The AA of green coffee showed highly significant differences across districts. The highest (72.55 %) level of AA was observed in coffee from Sheko district followed by coffee from Anderacha district while the lowest (66.66 %) levels of AA observed in coffee samples of SouthBench district (Table 2). Coffee from Getiba kebele in Anderacha district showed the highest (80.25 %) level of AA while coffee from Yokichichi kebele had the lowest (62.82 %) value in Anderacha district (Table 3).

Table 1. Roasting effect on biochemical content and antioxidant activity of BMS zones coffee dwb.

Coffee sample type	Parameters evaluated			
	Trigonelline (g/100g)	Chlorogenic acids (g/100g)	Caffeine (g/100g)	Antioxidant activity (%)
Green coffee	0.91	4.22	1.19	70.32
Roasted coffee	0.84	1.94	1.16	59.54
% losses due to roasting	7.69	54.00	2.52	15.33
P-value	<0.0001	<0.0001	0.1084	<0.0001

dwb = dry weight basis and g = gram.

Table 2. Biochemical and antioxidant activity of green coffee from districts of BMS zones (dwb).

Districts	Parameters evaluated			
	CAF (g/100g)	CGA (g/100g)	TRG (g/100g)	AA (%)
North Bench	1.21^{b}	4.19^{bc}	0.98^{a}	69.81^{de}
Guraferda	1.52^{a}	4.24^{bc}	1.00^{a}	70.55^{cd}
SouthBench	1.17^{b}	3.69^{d}	0.93^{b}	66.66^{f}
Menitshasha	1.16^{b}	4.25^{b}	0.90^{bc}	70.34^{cde}
Menitgoldiya	1.05^{c}	4.31^{b}	0.88^{cd}	70.82^{bc}
Shybench	1.16^{b}	4.32^{b}	0.88^{cd}	70.88^{bc}
Sheko	1.16^{b}	4.51^{a}	0.88^{cd}	72.55^{a}
Anderacha	1.15^{b}	4.32^{b}	0.86^{d}	71.67^{b}
Yeki	1.17^{b}	4.12^{c}	0.92^{b}	69.59^{e}
P-value	0.0001	0.0001	0.0001	0.0001
CV%	9.19	4.74	5.49	1.88
LSD (5%)	0.07	0.13	0.03	0.87

Means followed by the same letter(s) within a column are not significantly different at $P < 0.05$ AA = antioxidant activity, CAF = caffeine, CGA = chlorogenic acids, TRG = trigonelline, CV = Coefficient of variance, LSD = Least significance difference, g = gram and dwb = dry weight basis.

3.3. Biochemical content and antioxidant activity of roasted coffee

The roasted coffee biochemical content and antioxidant activity results for each district of the BMS zones are shown in Table 3. TRG, CGA, CAF contents and AA of roasted coffee showed highly significant differences among districts. Of all districts, NorthBench had the highest (0.98 g/100g) TRG contents in roasted coffee. While Menitshasha district had the lowest (0.76 g/100g) content of TRG in roasted coffee. The highest amount of CGA in roasted coffee was recorded in Anderacha (2.20 g/100g) district followed by Sheko (2.12 g/100g) district (Table 4). On the other hand, roasted coffee of SouthBench district registered the lowest (1.59 g/100g) amount of CGA. Similarly, highly significantly difference ($P < 0.01$) was noted for the CAF content of roasted coffee samples among districts. Roasted coffee of Guraferda district had the highest (1.41 g/100g) CAF content whereas the lowest content (0.98 g/100g) of CAF was achieved in Anderacha district which was statistically at par with Menitgoldiya, Sheko and Yeki districts. The AA content of roasted coffee varied among districts. Roasted coffee from Sheko district had the highest level (62.72 %) of AA while the lowest (55.97 %) was observed in roasted coffee of SouthBench district (Table 4).

3.4. Cup quality attributes correlation with biochemical content of green and roasted coffee

The correlations among biochemical contents of green coffee with coffee cup quality attributes were assessed and results are shown in Table 5. The coffee cup quality attributes across districts were presented in Table 6. Results showed that TRG content of green coffee was not significantly correlated with AI, AQ, AC, AS, BI and OCQ. On the other hand, significantly negative correlated with body and flavor. As indicated in Table 4 CGA content of green coffee was highly and significantly correlated with body, flavor and OCQ. Similarly, acidity was significantly correlated with green coffee CGA content. Moreover, astringency and bitterness were significantly and positively correlated with CAF content of green coffee.

Non-significant correlation was observed between trigonelline content with cup quality of roasted coffee; except positive significant correlation with flavor and highly significant positive correlation with body and overall cup quality (Table 7). The CGA content of roasted coffee was highly and significantly correlated with both body and flavor. Acidity and OCQ were showed positive and significant correlation with CGA content of roasted coffee (Table 7). However, other quality attributes did not show significant correlation with CGA content of roasted coffee. With the exception of the highly significant correlation of CAF content of roasted coffee with astringency and bitterness there was no significant correlation with any cup quality attributes (Table 7). There was no significant correlation between AA of roasted coffee with any of the coffee quality attributes except the positive and significant correlation with flavor (Table 7).

3.5. Correlation of biochemical content and antioxidant activity of green and roasted coffee

Green and roasted coffee biochemical contents and antioxidant activity correlations were assessed and results presented in Table 8. CAF content in green coffee showed highly significant correlations with TRG and CAFr (in roasted) while highly significant negative correlation achieved with TRGr (in roasted) coffee. CGA in green coffee were highly positive significant correlation was achieved with TRGr and CGAr in roasted coffee whereas highly negative significant correlation with CAFr (in roasted) coffee was revealed. TRG content in green coffee was highly significant correlation with CAFr in roasted coffee. TRGr in roasted coffee was significantly correlated with CGAr in roasted coffee. Highly negative significant correlation was noted between CGAr and CAFr both in roasted coffee (Table 8). The AA of green coffee was highly significant correlation with TRG, CGA and CGAr in roasted coffee. While positive significant

Table 3. Biochemical and AA of green and roasted coffee of samples in kebeles.

Ser. No	District	Kebele	TRG g/100g	CGA g/100g	CAF g/100g	TRGr g/100g	CGAr g/100g	CAFr g/100g	AA (%)	AAr (%)
1	NorthBench	Endekel	1.06	4.34	1.16	1.00	1.90	1.44	70.64	61.29
2	NorthBench	Dakin	1.07	4.49	1.54	0.97	2.13	1.19	73.11	64.35
3	NorthBench	Uka	1.04	4.38	1.37	1.01	1.94	1.44	70.75	59.39
4	NorthBench	Tishu	0.89	3.58	1.03	1.01	1.55	1.45	65.76	55.22
5	NorthBench	Tebenjayazhi	0.82	4.41	0.85	1.03	2.01	1.21	71.30	59.84
6	NorthBench	Bosoqa	0.96	3.95	1.31	0.84	1.69	1.32	67.35	55.55
7	Guraferda	Chodeta	0.88	3.91	1.33	0.81	1.68	1.39	67.25	57.46
8	Guraferda	Kuja	1.01	4.39	1.46	0.92	1.95	1.41	70.83	59.45
9	Guraferda	Danqela	1.08	4.97	1.46	1.03	2.52	1.40	76.58	64.26
10	Guraferda	Berji	1.06	4.80	1.52	0.95	2.41	1.45	74.76	62.73
11	Guraferda	Siega	0.91	4.22	1.65	0.81	1.88	1.29	69.71	58.52
12	Guraferda	Philiya	1.05	3.12	1.73	0.99	1.46	1.53	64.14	53.87
13	SouthBench	D/work	0.97	3.61	1.29	0.91	1.56	1.35	66.81	56.10
14	SouthBench	Kob	1.06	3.69	1.37	0.75	1.59	1.11	67.00	56.26
15	SouthBench	Jantuta	0.90	3.35	1.07	0.93	1.48	1.31	65.20	54.76
16	SouthBench	Janchu	0.89	4.09	1.15	0.90	1.76	1.14	68.20	57.26
17	SouthBench	Qite	0.88	3.81	1.06	0.84	1.64	1.15	67.19	56.41
18	SouthBench	Keberta	0.86	3.58	1.07	0.91	1.52	1.22	65.53	55.03
19	Menitshasha	Jemu	0.80	4.13	1.03	0.74	1.80	0.90	68.43	57.45
20	Menitshasha	Kudum	0.84	4.62	1.08	0.79	2.29	1.12	74.18	62.25
21	Menitshasha	Olmu	0.87	4.05	1.41	0.74	1.71	1.09	67.55	56.71
22	Menitshasha	Eara	1.01	4.31	1.17	0.77	1.89	1.01	70.60	59.26
23	Menitshasha	Erini	0.88	3.76	1.23	0.79	1.62	1.33	67.05	56.30
24	Menitshasha	Baro	0.98	4.63	1.06	0.73	2.31	1.22	74.25	62.31
25	Menitgoldiya	Chat	0.81	4.25	0.94	0.86	1.88	0.92	70.33	59.03
26	Menitgoldiya	Shokach	0.83	4.23	0.99	0.78	1.88	1.03	70.30	59.01
27	Menitgoldiya	Bachuma	0.85	4.45	1.07	0.88	2.08	1.01	72.87	63.16
28	Menitgoldiya	Kushanta	1.04	4.44	1.16	0.94	2.02	0.99	72.25	61.63
29	Menitgoldiya	Dilkuba	0.88	4.08	1.02	0.81	1.72	1.05	67.80	56.92
30	Menitgoldiya	AdyAbeba	0.90	4.43	1.15	0.92	2.01	1.01	71.37	59.90
31	ShyiBench	YtikmtEsht	0.90	4.46	1.07	0.88	2.11	1.23	73.02	61.28
32	ShyiBench	Kuka	0.97	4.69	1.08	0.98	2.32	1.33	74.32	62.37
33	ShyiBench	Adisalem	0.94	4.29	1.16	0.91	1.89	1.27	70.52	59.20
34	ShyiBench	Ziyagen	0.86	4.44	1.19	0.80	2.05	1.31	72.32	63.70
35	ShyiBench	Shyibench	0.84	4.05	1.19	0.85	1.69	1.31	67.75	56.88
36	ShyiBench	Bakbas	0.81	3.96	1.26	0.80	1.69	1.26	67.37	56.56
37	Sheko	Gayziqa	0.91	4.13	1.29	0.81	1.80	1.02	68.52	57.53
38	Sheko	Shayta	0.95	4.51	1.34	0.77	2.15	0.93	73.41	61.60
39	Sheko	Selale	0.90	4.44	1.03	0.73	2.03	1.04	72.82	66.11
40	Sheko	Wosheqa	0.84	4.19	1.05	0.78	1.86	1.15	69.49	62.33
41	Sheko	Gizmeriyt	0.84	5.19	1.09	0.93	2.61	1.10	77.05	64.65
42	Sheko	Shime	0.83	4.60	1.14	0.74	2.28	0.89	74.01	64.11
43	Anderacha	Modi	0.84	4.15	1.02	0.77	1.81	0.88	68.89	58.83
44	Anderacha	Tugri	0.80	4.16	1.00	0.75	1.85	1.03	69.21	58.10
45	Anderacha	Getiba	0.84	5.42	1.20	0.84	3.54	1.01	80.25	67.31
46	Anderacha	Beshifa	0.92	4.56	1.37	0.72	2.25	0.97	73.71	61.85
47	Anderacha	Gemadro	0.92	4.84	1.25	0.79	2.44	0.99	75.12	63.03
48	Anderacha	Yokichichi	0.83	2.80	1.04	0.78	1.30	1.00	62.82	52.76
49	Yeki	Adisalem	0.93	4.89	1.18	0.72	2.47	0.96	75.69	65.51
50	Yeki	Erimich	0.83	4.13	1.23	0.81	1.79	1.17	68.34	57.38
51	Yeki	Kubito	0.80	3.60	1.02	0.72	1.55	1.09	65.91	56.35
52	Yeki	Adissbirihan	0.97	4.55	1.32	0.75	2.18	1.01	73.57	63.74
53	Yeki	Shosha	0.94	3.88	1.22	0.82	1.66	1.01	67.21	56.43
54	Yeki	Hibretfere	1.06	3.65	1.03	0.79	1.58	1.03	66.82	56.11
	Min		0.80	2.80	0.85	0.72	1.30	0.88	62.82	52.76
	Max		1.08	5.42	1.73	1.03	3.54	1.53	80.25	67.31
	Ave		0.92	4.22	1.19	0.85	1.94	1.16	70.32	59.55
	SE		0.01	0.07	0.03	0.01	0.05	0.02	0.50	0.47

AA = antioxidant activity, CAF = caffeine, CGA = chlorogenic acids, TRG = trigonelline, AAr = antioxidant activity (in roasted), CAFr = caffeine (in roasted), CGAr = chlorogenic acids (in roasted) and TRGr = trigonelline (in roasted).

Table 4. Biochemical and antioxidant activity of roasted coffee from districts of BMS zones (dwb).

Districts	Parameters evaluated			
	CAFr (g/100g)	CGAr (g/100g)	TRGr (g/100g)	AAr (%)
North Bench	1.34^{ab}	1.87^{d}	0.98^{a}	59.28^{de}
Guraferda	1.41^{a}	1.98^{c}	0.92^{ab}	59.38^{cde}
SouthBench	1.21^{c}	1.59^{e}	0.87^{b}	55.97^{f}
Menitshasha	1.11^{d}	1.94^{c}	0.76^{d}	59.05^{e}
Menitgoldiya	1.00^{e}	1.93^{c}	0.86^{bc}	59.94^{bcd}
Shybench	1.29^{bc}	1.96^{c}	0.87^{b}	60.00^{bc}
Sheko	1.02^{e}	2.12^{b}	0.79^{cd}	62.72^{a}
Anderacha	0.98^{e}	2.20^{a}	0.78^{d}	60.32^{b}
Yeki	1.05^{ed}	1.87^{d}	0.77^{d}	59.25^{e}
P-value	0.0001	0.0001	0.0001	0.001
CV%	11.26	4.46	13.01	1.75
LSD (5%)	0.09	0.06	0.07	0.69

Means followed by the same letter(s) within a column are not significantly different at $P < 0.05$; AAr = antioxidant activity in roasted, CAFr = caffeine in roasted, CGAr = chlorogenic acids in roasted, TRGr = trigonelline in roasted, CV = Coefficient of variance, LSD = Least significance difference, g = gram and dwb = dry weight basis.

Table 5. Cup quality correlation with biochemical content and antioxidant activity in green coffee.

Cup Quality	Parameters evaluated			
	Caffeine	Chlorogenic acids	Trigonelline	Antioxidant activity
Aromatic intensity	-0.006^{ns}	0.031^{ns}	-0.014^{ns}	-0.010^{ns}
Aromatic quality	0.006^{ns}	0.092^{ns}	-0.010^{ns}	0.040^{ns}
Acidity	-0.026^{ns}	0.161*	-0.109^{ns}	0.057^{ns}
Astringency	0.196*	-0.043^{ns}	0.136^{ns}	0.061^{ns}
Bitterness	0.168*	-0.024^{ns}	0.062^{ns}	0.028^{ns}
Body	-0.117^{ns}	0.273**	-0.226**	0.027^{ns}
Flavor	-0.083^{ns}	0.259**	-0.180*	0.097^{ns}
Overall cup quality	0.038^{ns}	0.209**	-0.091^{ns}	0.077^{ns}

Significance: ns = non-significant, * = $P < 0.05$ and ** = $P < 0.01$.

correlation with CAF and negatively significant correlation with TRG in roasted coffee were achieved. Correlation of AAr in roasted coffee with CGA, AA in green coffee and CGAr in roasted coffee was highly significant. On the other hand AAr in roasted coffee showed negatively and highly significant correlation with its CAFr in roasted coffee (Table 8).

4. Discussion

The present research work determined the effect of environment on the biochemical composition of green coffee beans from nine districts of BenchMaji and Sheka zones. The average trend values showed variation among evaluated coffee samples both for the biochemical content in green bean and roasted coffee. The biochemical contents of coffee varied among districts as well as Kebeles due to environmental difference. This research expanded the scope and clarified the correlation of coffee quality with biochemical composition (caffeine, trigonelline and chlorogenic acid) of green and roasted coffee of BenchMaji and Sheka zones. The study further discussed green and roasted coffees antioxidant activity and its correlation with coffee quality.

Table 6. Cup quality attributes of coffee samples in districts.

Districts	Coffee cup quality attributes							
	AI	AQ	Acidity	Astringency	Bitterness	Body	Flavor	OCQ
North Bench	4.06	4.25	8.31	4.39	4.44	8.06	8.08	8.19
Guraferda	3.89	3.97	7.75	4.31	4.28	7.67	7.50	7.81
SouthBench	3.82	3.82	7.92	4.19	4.31	7.75	7.69	7.81
Menitshasha	4.14	4.39	7.97	4.56	4.50	7.89	7.81	7.83
Menitgoldiya	4.00	4.03	7.78	4.03	4.08	7.72	7.56	7.65
ShyBench	4.11	4.22	7.95	3.97	4.08	7.81	7.69	7.81
Sheko	3.61	3.67	7.56	3.69	3.81	7.64	7.36	7.53
Anderacha	4.06	4.14	8.39	4.22	4.42	8.06	8.25	8.28
Yeki	3.72	3.58	7.33	3.53	3.58	7.33	7.06	7.19
Sd	0.36	0.51	0.59	0.54	0.57	0.58	0.65	0.58
LSD (5%)	0.20	0.26	0.29	0.31	0.35	0.36	0.35	0.29

AI = Aromatic Intensity, AQ = Aromatic Quality, OCQ = Overall Cup Quality.

Table 7. Roasted coffee biochemical content and antioxidant activity correlation with cup quality.

Cup Quality	Parameters evaluated			
	CAFr	CGAr	TRGr	AAr
Aromatic intensity	0.057^{ns}	-0.019^{ns}	-0.017^{ns}	-0.005^{ns}
Aromatic quality	0.109^{ns}	0.038^{ns}	-0.008^{ns}	0.041^{ns}
Acidity	-0.003^{ns}	0.152*	0.176^{ns}	0.074^{ns}
Astringency	0.291**	-0.022^{ns}	-0.029^{ns}	0.059^{ns}
Bitterness	0.221**	-0.017^{ns}	-0.005^{ns}	0.034^{ns}
Body	-0.146^{ns}	0.201**	0.269**	0.140^{ns}
Flavor	-0.094^{ns}	0.223**	0.173*	0.172*
Overall cup quality	-0.008^{ns}	0.182*	0.204**	0.116^{ns}

Significance: ns = non-significant, * = P < 0.05 and ** = P < 0.01.
AAr = antioxidant activity in roasted, CAFr = caffeine in roasted, CGAr = chlorogenic acids in roasted and TRGr = trigonelline in roasted.

Table 8. Correlation among biochemical compositions and AA of green and roasted coffee.

	Caffeine	CGA	Trigonelline	CAFr	CGAr	TRGr	AA	AAr
Caffeine	1							
CGA	-0.106^{ns}	1						
Trigonelline	0.663**	-0.070^{ns}	1					
CAFr	0.555**	-0.325**	0.532**	1				
CGAr	-0.022^{ns}	0.923**	-0.023^{ns}	-0.260**	1			
TRGr	-0.206**	0.250**	-0.050^{ns}	0.020^{ns}	0.162*	1		
AA	0.177*	0.786**	0.249**	-0.012^{ns}	0.848**	-0.170*	1	
AAr	-0.084^{ns}	0.907**	0.004^{ns}	-0.301**	0.885**	-0.148^{ns}	0.815**	1

Significance: ns = non-significant, * = P < 0.05 and ** = P < 0.01.
AA = antioxidant activity, CGA = Chlorogenic acids, AAr = antioxidant activity in roasted, CAFr = caffeine in roasted, CGAr = chlorogenic acids in roasted and TRGr = trigonelline in roasted.

Significant variation in TRG, CGA and CAF was observed among coffee samples collected from BMS zones. Furthermore, all Districts varied for all biochemical contents evaluated. In the present study, the range of TRG, CGA and CAF content varied from 0.80 to1.08 g/100g, 2.80–5.42 g/100g and 0.85–1.73 g/100g of green coffee (dwb), respectively. These values are generally within the range of values previously reported for green Arabica coffee beans (Farah et al., 2006). The results of the present study are also in agreement with other previous research results reported by different authors (Ky et al., 2001; Yigzaw et al., 2008; Abiyot et al., 2011; Kassaye et al., 2017; Mohammed et al., 2018) that reported the presence of significant variations among coffee types of Arabica coffee in respect of biochemical compositions. The variation observed in terms of chemical contents of green and roasted coffee samples could be attributed to the difference in the growing environment conditions such as altitude, soil type, rainfall and other agricultural practices. Coffee trees that are grown in different agro-ecological zones can have variation in their rate of growth and accumulation of biochemical constituents. In addition variability of chemical composition in Ethiopian Arabica coffee was reported by different researchers (Yigzaw et al., 2008; Abiyot et al., 2011; Scholz et al., 2016).

The content of CAF was not affected by coffee roasting. This is due to roasting reaction did not change CAF into volatile or to another chemical form. Similar observation confirmed that caffeine remained unchanged during roasting (Joët et al., 2010). To the contrary during roasting the content of trigonelline, chlorogenic acids and antioxidant activity were significantly decreased. Due to the Maillard reaction some amount of TRG and CGA changed to other form. Decrease in AA of the coffee beans as the roasting degree increases, which is mainly associated with the degradation of chlorogenic acids (Somporn et al., 2011). The roasted coffee TRG, CGA and CAF content ranged from 0.72 to1.03 g/100g, 1.30–3.54 g/100g and 0.88–1.53 g/100g respectively. Roasting creates complex aroma of coffee due to pyrolysis, degradation, and Maillard reaction (Yeretzian et al., 2003). Reduction of Trigonelline and chlorogenic acid contents of coffee occurs during roasting due to simultaneously chemical reactions and changes (Michaela et al., 2013). Roasting process induces transformation of chemical contents through further chemical and physical changes that may greatly affect the sensory quality of coffee beverages. The water solubility of coffee essential oil is a cause for the development odor and flavor during roasting (Toci et al., 2013).

The correlations among biochemical contents and antioxidant activity of green and roasted coffee were assessed. Accordingly, caffeine and chlorogenic acids had negative correlation which however was not significant. According to D'Amelio et al. (2009) a complex correlation exists between CAF and CGA of coffee beans. Coffee quality is influenced by its biochemical contents. Correlation of cup quality with different biochemical contents of coffee was reported by Anne (2014). Inherent chemical constituents of green coffee are among the quality characteristics in addition to physical appearances and organoleptic cup quality. Strong positive correlation between the level of most of CGA monoesters and low cup quality was reported (Farah et al., 2006). There was positive significant correlations among cup quality attributes. The existence of correlation between coffee cup quality and some chemical attributes underlines the fact that biochemical contents of coffee influence quality. Hence chemical analysis of green beans may be used as an additional tool for evaluating coffee quality. Presence of variability among the biochemical contents such as caffeine, trigonelline and chlorogenic acids of Ethiopian green coffee was reported (Yigzaw et al., 2007). Silvarolla et al. (2004) also reported extensive variation in caffeine, chlorogenic acid and trigonelline contents of coffee. Variation and correlation of organoleptic quality and biochemical attributes of Arabica coffee are also reported by previous studies (Yigzaw et al., 2007; Abiyot et al., 2011). These correlations among cup quality and biochemical contents can be used as an additional tool for coffee quality evaluation (Farah et al., 2006). CGA is known to be responsible for astringency, bitterness, aroma

formation and acidity to the coffee brew (Farah et al., 2006). CGAs play an important role in the formation of roasted coffee flavor and have a marked influence in determining coffee cup quality (Farah et al., 2005). Trigonelline showed a significant negative correlation with body and caffeine (Anne, 2014). Odor and flavor losses are the consequence of water solubility of coffee essential oils (Toci et al., 2013). CGAs, phenolic compounds, are known to be responsible for astringency and aroma formation.

The antioxidant activity of coffee from the study area varied among districts as well as kebeles within district. AA content of coffee decreased as a function of roasting which is in agreement with existing literature which state that the AA content of coffee decreases as degree of roasting increases (Del Castillo et al., 2002). However, this is in contrast to Liu and Kitts (2011) and Perrone et al. (2012) who found greater AA for light roast brews while Nicoli et al. (1997) reported higher AA for medium and dark roast brews. Coffee with high amount of CGA had more amount of AA content. This amplifies the fact that CGA is positively correlated with AA content of coffee. A progressive decrease in antioxidant activity mainly associated with CGA in green bean with increasing degree of roasting was observed (Del Castillo et al., 2002). Most biochemical profile values indicated that, owing to its unique growing conditions, the study area has the potential to deliver good quality specialty coffee for the world coffee market.

5. Conclusion

The results of the present study showed that coffee from BenchMaji and Sheka possess considerable biochemical differences and antioxidant potential, which in turn are influenced by coffee origin and growing environmental conditions. Correlations exist between coffee quality attributes and biochemical composition of green and roasted coffee beans of BMS zones. Our research result also confirmed the presence of correlation among the biochemical contents and antioxidant activity of green and roasted coffee. Positive correlation is noted between the antioxidant content of green and roasted coffee. The cup quality of coffee is immensely influenced by the biochemical contents of the beans after roasting and brewing. Inherent chemical constituent of green coffee is among the quality characteristics which influence the physical appearances and organoleptic cup quality of the final coffee. Positive and significant correlations are observed among all the sensory characteristics. Correlations between coffee cup quality and some chemical attributes is an indication of the biochemical content of coffee influence quality. As the intensity of roasting increases, the greater destruction of the phenolic compounds exists this may not be compensated by the formation of other compounds. Hence, coffee before roasting shows greater antioxidant capacity due to the greater polyphenol content (CGA). This research work was investigative and illustrative, in that the coffee biochemical profile of study area. The results provide good quality coffee which fulfills the special coffee attributes of vast distribution of the quality of coffee produced in the BenchMaji and Sheka zones.

Declarations

Author contribution statement

Abrar Sualeh: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Kassaye Tolessa: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ali Mohammed: Conceived and designed the experiments; Wrote the paper.

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Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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