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Full Length Research Paper

Sensory Evaluation of beverage characteristics and biochemical components of Coffee Genotypes

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Arabica coffee (*Coffea arabica* L.) is known for the production of high quality beverage while Robusta coffee (*Coffea canephora* Pierre) has been characterized as a neutral, weak flavored and occasionally with strong acid and pronounced bitterness. Viable and reasonably fertile interspecific hybrids can easily be obtained from crosses between the allotetraploid *C. arabica* L. and induced autotetraploid forms of *C. canephora* P. This study was carried out to determine beverage quality characteristics and biochemical components of 15 coffee genotypes, nine of them being interspecific Arabusta F_1 hybrids. Beverage quality was determined by a panel of six judges using the prescribed sensory evaluation procedures, while caffeine, oil, trigonelline, total chlorogenic acids (CGA) and sucrose were analyzed in green coffee samples using recommended methodologies. The results indicated significant ($p<0.05$) variations among the genotypes for all the sensory attributes. The total score, which is a reflection of the broad coffee quality performance showed that SL34 and SL28 (which served as reference in sensory quality), were not significantly different from Arabusta hybrids SL34 x UT8, SL28 x UT8, N39 x UT8, SL34 x UT6, CaturraxUT6 and SL28 x UT6. The quality of some Arabusta hybrids was found to be similar to that of pure Arabica genotypes. Similarly, biochemical variables revealed significant ($p<0.05$) variations for caffeine, oil and sucrose, among genotypes except for CGA and trigonelline which were not significantly different. There were positive significant correlations between all the sensory characteristics. Sucrose showed significant ($P<0.05$) correlations with fragrance flavour, aftertaste and overall. Trigonelline showed a significant negative correlation with body and caffeine. All the Arabusta hybrids scored specialty grade (80 points and above for total score) and therefore future studies on their performance in many locations with more variable climatic conditions is recommended.

Key words: Coffee, Arabusta, F_1 interspecific hybrids, sensory variables, biochemical components.

INTRODUCTION

Coffee belongs to the genus *Coffea* in the Rubiaceae family that contains 640 generas and 1000 species (Charrier and Berthaud, 1985). *Coffea arabica* L. commonly referred to as Arabica coffee, is tetraploid

(2n = 4x = 44) and is known for the production of high quality beverage (Gichuru et al., 2008; Kathurima et al., 2009; Gichimu and Omondi, 2010). *Coffea canephora* Pierre, also referred to as Robusta coffee, is diploid (2n = 2x = 22) and generally self-incompatible (Combes et al., 2000; Lashermes et al., 2011). Robusta coffee has been characterized as a neutral, weak flavored and occasionally with strong acid and pronounced bitterness (Bertrand et al., 2003). Robusta coffee is less susceptible to pests than Arabica coffee (Tshilenge et al., 2009)

The transfer of desirable genes particularly for disease resistance from diploid species like *C. canephora* and *C. liberica* into tetraploid *C. arabica* cultivars without affecting quality traits has been a major objective of Arabica coffee breeding. However, the ploidy level differences between the tetraploid *C. arabica* and other diploid coffee species has been a major bottleneck for interspecific gene transfer (Ky et al., 2001a).

Viable and reasonably fertile interspecific hybrids between *C. arabica* and various diploid species including *C. canephora* have been successfully produced (Lashermes et al., 2011). Such hybrids have been produced through crosses between the allotetratploid *C. arabica* with induced autotetraploid forms of *C. canephora* obtained through doubling of the chromosome number by colchicine treatment (Owuor and Van Der Vossen, 1981). The first successful interspecific hybrids between induced tetraploid *C. canephora* and *C. arabica* were made in Brazil in 1950. Those hybrids have been used in coffee breeding programs to introgress genes for resistance to coffee Coffee Leaf Rust (*Hemileia vastatrix*) and Coffee Berry Disease (*Colletotrichum kahawae*) from *C. canephora* into *C. arabica* or to improve the quality of Robusta coffee by direct use of the F_1 Arabusta hybrids (Owuor and Van der Vossen, 1981). New Arabica coffee cultivars with better quality, higher yield potential and resistance to diseases have started to replace the traditional varieties on a large scale in several countries (Gichimu and Omondi, 2010). Arabica coffee plants have a narrow genetic base attributed to the few seeds/plants used for dissemination, successive genetic reduction due to human impacts and reproduction nature of Arabica coffee which is autogamous (Teressa et al., 2010). Reduced genetic diversity is reported to compromise the ability of populations to evolve so that they can cope up with environmental changes and thus reducing their chances of long-term persistence (Frankham et al., 2002). As for many other crops, evaluation of the genetic diversity and available resources within the genus *Coffea* is an important step in coffee breeding (Cubry et al., 2008).

Coffee is one of the most popular beverages consumed all over the world with a total annual consumption of coffee exceeding 400 billion cups (Nebesny and Budryn, 2006). Sensory assessment is one of the methods used in identifying the market acceptability especially in food or drink based products. It is also used for product development and improvement as most important factors for a particular market can be identified and improved (Lazim and Suriani, 2009). For coffee, quality of liquor also referred to as beverage quality, determines the desirability of coffee for consumption purposes and acts as a yardstick for price determination (Agwanda et al., 2003; Kathurima et al., 2009; Gichimu et al., 2012). Production and supply of coffee with excellent quality is important for coffee exports and success of a new coffee variety depends to a great extent on its bean and beverage quality (Gichimu et al., 2012). Different levels of biochemical components in coffee contribute variously to the final quality of the cup (Buffo and Freire, 2004). The presence of those biochemical components could have a favorable effect on the coffee beverage quality, as for trigonelline and sugars, or an unfavorable one, as for chlorogenic acids and caffeine (Clifford, 1985; Macrae, 1985). Trigonelline is considered to be important for both taste and nutrition (Ky et al., 2001a). Coffee oil carries most of the coffee aroma and contributes to brew viscosity (Buffo and Freire, 2004). This study was carried out with an aim of assessing the variation of cup quality traits and biochemical components of 15 coffee genotypes (including 9 interspecific Arabusta F_1 hybrids). The study also aimed at determining the suitability of the interspecific F_1 Arabusta in the improvement of the beverage quality of Robusta coffee or for further selection and use as coffee varieties.

MATERIALS AND METHODS

Description of the study site

The study was conducted at the Coffee Research Station (CRS), Ruiru, about 33 km North of Nairobi. CRS lies within the upper midland (UM2) at latitude 1° 06'S and longitude 36° 45'E and is approximately 1620 m above sea level. The area receives a bimodal rainfall of 1063 mm annually with mean temperature of 19°C (min. 12.8°C, max. 25.2°C). The soils are classified as complex humic nitisols and plinthic ferrasol (Jaetzold and Schmidt, 1983). They are well drained, deep, reddish brown, slightly friable clays with murram sections occasionally interrupting. The soil pH ranges from 5 to 6 (Jaetzold and Schmidt, 1983).

Test materials

The coffee genotypes in this study comprised of nine interspecific Arabusta F_1 hybrids, two commercial arabica coffee varieties (namely SL 28 and SL 34), two museum accessions (N39 and Caturra), Hibrido De Timor (HDT), a natural Arabusta accession and a diploid Robusta variety (Table 1). SL 28 and SL 34 served as reference in quality evaluation. The F_1 hybrids are interspecific crosses between four Arabica and four induced tetraploid Robusta accession. Induced tetraploid Robusta accessions (ex Fr.) were introduced from Uganda. These genotypes are conserved by Coffee Research Foundation (CRF) at the main station, Coffee Research Station (CRS) and Oakland Estate. Cherry samples for analysis were collected during the peak harvesting period of October to December, 2012. Ripe healthy berries were harvested from each of the genotypes and processed using wet processing

Table 1. List of coffee genotypes evaluated for sensory and biochemical components.

Genotype	Status	Introduced from
SL28 x UT3	Arabusta F1 Hybrid	Kenya
SL28 x UT6	Arabusta F1 Hybrid	Kenya
SL34 x UT6	Arabusta F1 Hybrid	Kenya
N39 x UT6	Arabusta F1 Hybrid	Kenya
Caturra x UT6	Arabusta F1 Hybrid	Kenya
SL28 x UT8	Arabusta F1 Hybrid	Kenya
SL34 x UT8	Arabusta F1 Hybrid	Kenya
N39 x UT8	Arabusta F1 Hybrid	Kenya
SL28 x UT10	Arabusta F1 Hybrid	Kenya
SL34	Commercial variety	Kenya
SL28	Commercial variety	Kenya
N39	Museum accession	Lyamungu Tanzania
Caturra	Museum accession	Brazil
Hibrido De Timor	Natural Arabusta	Portugal
Robusta	Diploid Robusta	Uganda

Table 2. Descriptors used by the sensory panel to describe the sensory properties of the coffee samples.

Scale	Attribute	Word anchor
1 - 10	Fragrance/Aroma	Very poor - Outstanding
1 - 10	Flavour	Very poor - Outstanding
1 - 10	Aftertaste	Very poor - Outstanding
1 - 10	Balance	Very poor - Outstanding
1 - 10	Preference	Very poor - Outstanding
1 - 10	Acidity	Very flat - Very bright
1 - 10	Body	Very thin - Very heavy

procedures (Mburu, 2004). The cherry samples were pulped, fermented, washed, wet parchment dried to final moisture content of 10.5-11% and then hulled to produce green coffee beans for analysis (Kathurima et al., 2010). The laboratory experiment was carried out in a complete randomized design in six replicates each representing a judge.

Roasting and sensory analysis

The green coffee beans were roasted within 24 h of evaluation, in order to ensure a fresh brew, using a laboratory roaster (Probat BRZ 4, Rhein, Germany). The beans were roasted to a medium level roast and allowed to rest for at least eight hours. The roasted samples were ground individually (five cups per sample), using a sample grinder (Probat vtv-633T, Rhein Germany), not more than 15 min before infusion with water. The samples were weighed out to the predetermined ratio of 8.25 g per 150 ml of water. Sensory evaluation was conducted using the procedures described by Lingle (2001). Seven sensory variables namely; fragrance/aroma, flavour, aftertaste, acidity, body, balance and overall were assessed and scored together with three process control variables (uniformity, clean cup and sweetness) by a panel of six trained cuppers on a 10-point scale whose descriptors are as Table 2.

Fragrance is the smell of the ground coffee when still dry and aroma is the smell of the coffee when infused with hot water while aftertaste are vapors remaining after the coffee is swallowed (Lingle, 2001). Balance is the assessment of how well the flavour, aftertaste, acidity and body fit together in a synergistic combination (Kathurima, 2013). The attribute overall, is a reflection of the panelists personal appraisal based on the holistically integrated rating of the sample as perceived by the individual panelist (Kathurima, 2013). All the sensory parameters (including the three process control parameters) were added together to constitute the total score which was a reflection of the broad coffee quality performance. On the basis of scores obtained, the coffee was classified into either specialty grade (80-100 points) or commercial grade (79 points and below) (Specialty Coffee Association of America, SCAA).

Determination of coffee biochemical components

The genotypes were analyzed for five attributes namely, caffeine, trigonelline, oils, sucrose and chlorogenic acids (CGA). Portions of the green coffee samples were placed in small plastic bottles and stored under -80°C. After 24 h of freezing, the samples were ground in liquid nitrogen using an analytical mill (Model A10, IKA work inc. Wilmington, NC, USA). Caffeine, trigonelline and CGA were extracted from green coffee powder by refluxing in distilled water. Caffeine, trigonelline and CGA were analysed using a HPLC system (KNEUR) equipped with a Supel Co. discovery diode array detector at three wavelengths, 278 nm for caffeine, 266 nm for trigonelline and 324 nm for CGA. Sucrose was extracted from green coffee powder using the method of Osborne and Voogt (1978). Sucrose was analysed using a HPLC system (KNEUR) equipped with a Eurospher 100-5 NH_2 column and a refractive index detector. Caffeine, trigonelline CGA and sucrose were identified by comparing the retention times of standards and their concentrations calculated from peak areas using calibration equations. Coffee oil was analysed as outlined in the AOAC (1995). The laboratory experiment was carried out in a complete randomized design (CRD) in four replicates each representing different extraction time.

Data analysis

Sensory and biochemical data were subjected to analysis of

Table 3. Mean sensory characteristics and specialty classification of fifteen coffee genotypes evaluated in this study.

Genotype	Sensory variables							
	Fragrance	Flavour	Aftertaste	Acidity	Body	Balance	Overall	Mean total score
SL28	7.8^{a}	8.04^{a}	7.88^{ab}	8.17^{a}	7.79^{a}	7.79^{a}	8.04^{a}	85.54
SL34	7.8^{a}	8.08^{a}	7.96^{a}	8.13^{a}	7.75^{a}	7.79^{a}	7.92^{ab}	85.46
CaturraxUT8	7.7^{ab}	7.58^{ab}	7.54^{abc}	7.46^{abc}	7.46^{ab}	7.50^{ab}	7.38^{bcdef}	83.83
N39 x UT8	7.7^{ab}	7.63^{ab}	7.63^{abc}	7.63^{abc}	7.75^{a}	7.58^{ab}	7.67^{abcd}	83.67
SL34 x UT6	7.7^{ab}	7.67^{ab}	7.63^{abc}	7.63^{abc}	7.54^{ab}	7.63^{ab}	7.54^{abcde}	83.54
CaturraxUT6	7.6^{ab}	7.71^{ab}	7.63^{abc}	7.58^{abc}	7.58^{ab}	7.63^{ab}	7.63^{abcd}	83.38
SL28 x UT8	7.6^{ab}	7.67^{ab}	7.79^{abc}	7.79^{abc}	7.50^{ab}	7.63^{ab}	7.67 ^{abcd}	83.29
SL28 x UT6	7.5^{abc}	7.54^{abc}	7.54^{abc}	7.58^{abc}	7.71^{a}	7.50^{abc}	7.50 ^{abcde}	82.92
SL34 x UT8	7.5^{abc}	7.67^{bc}	7.79^{abc}	7.83^{ab}	7.63^{a}	7.63^{ab}	7.75^{abc}	82.17
N39 x UT6	7.5^{abcd}	7.46^{abc}	7.29^{bcd}	7.33^{bcd}	7.46^{ab}	7.42^{abcd}	7.33^{cdef}	81.75
SL28 x UT3	7.4^{abcd}	7.17^{bc}	7.38^{abcd}	7.17^{bcd}	7.38^{ab}	7.04^{d}	7.17^{def}	81.33
N 39	7.3^{abcd}	7.50^{abc}	7.46^{abc}	7.58^{abc}	7.50^{ab}	7.42^{abcd}	7.38^{bcdef}	80.67
Caturra	7.1^{bcd}	6.58^{d}	6.88^{d}	6.88^{de}	7.00^{b}	7.08^{cd}	6.96^{f}	79.96
Robusta	7.0^{cd}	6.54^{d}	6.88^{d}	6.58^{e}	7.42^{ab}	6.71^{e}	6.54^{g}	78.50
HDT	6.96^{d}	7.00^{c}	7.17^{cd}	7.08^{cde}	7.46^{ab}	7.25^{bcd}	7.04^{ef}	77.04
LSD(p<0.05)	0.260	0.337	0.335	0.392	0.295	0.259	0.316	
P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.012	< 0.0001	< 0.0001	

Means along a column not sharing the same letter are significantly different (P<0.05) using Student-Newman-Keuls test. HDT-Hibrido De Timor. The means for total score were not separated as they were derived from additions.

Table 4. The first two principle components (PC) of the seven sensory variables.

Variable	PC1	PC2
Fragrance/aroma	0.371	-0.181
Flavour	0.395	-0.019
Aftertaste	0.392	0.001
Acidity	0.388	-0.175
Body	0.318	0.926
Balance	0.383	-0.223
Overall	0.393	-0.17
Eigen value	6.309	0.384
Variability (%)	90.133	5.489
Cumulative (%)	90.133	95.623

variance (ANOVA) using COSTAT statistical software. Student-Newman-Keuls (SNK5%) test was used to separate the means at 5% level of significance. Multivariate analyses was done using principle component analysis (PCA) for both sensory quantitative variables and biochemical components the characteristics plotted for important principle components using XLSTAT statistical software, version 2012.

Sweetness refers to a pleasing fullness of flavor as well as any obvious sweetness and its perception is the result of the presence of certain carbohydrates. Clean cup refers to a lack of interfering negative impressions from first ingestion to final aftertaste. Any non-coffee like tastes or aromas will disqualify an individual cup. Two (2) points are awarded for each cup displaying the attribute of clean Cup. Uniformity refers to consistency of flavor of the different cups of the sample tasted. If the cups taste different, the rating of this aspect would not be as high. Two (2) points are awarded for each cup displaying this attribute, with a maximum of 10 points if all 5 cups are the same. To get the total score, the scores of sweetness, clean cup and uniformity were added to the scores of the other attributes.

RESULTS

Diversity of coffee genotypes as determined by sensory variables

A total of 15 genotypes were evaluated for sensorial attributes. The results indicated highly significant ($p<0.05$) variation among the genotypes for all the sensory attributes studied (Table 4). The commercial varieties SL28 and SL34 got the highest scores in all the sensory variables studied, though they were not significantly different from the Arabusta hybrids for several traits. All the sensory attributes attained scores above 6.5 meaning they were all rated as good by the panel of assessors. Robusta and Caturra were significantly ($p<0.05$) different from the other genotypes in flavour and acidity. The overall scoring aspect is meant to reflect the holistically integrated rating of the sample as perceived by the individual panelist. Robusta showed the lowest score in terms of balance, acidity, flavor and overall. All interspecific F_1 Arabusta hybrids genotypes were characterized with bitterness as was Robusta and HTD.

All the genotypes scored a maximum of 10 points for each of the variables clean cup, sweetness and uniformity, which were added to the scores of the other sensory variables to classify the coffee as specialty grade (80 to 100 points) or commercial grade (79 and below).

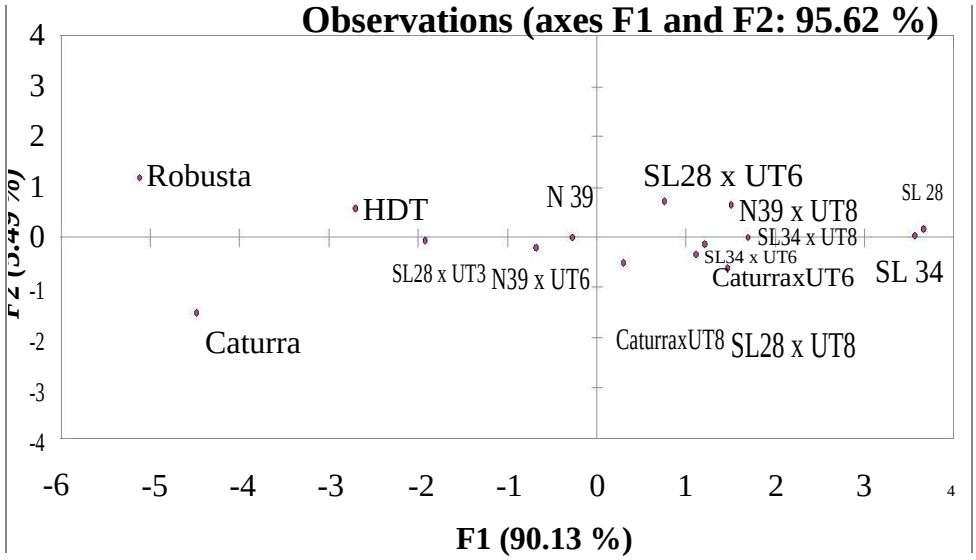

Figure 1. Principle component (PC) analysis plot of first two principle components, illustrating relationship among the coffee genotypes assessed for sensory attributes.

The mean total scores of the coffee genotypes in this study is shown in Table 3. SL 28 and SL34 scored the highest but similar to all the interspecific Arabusta F_1 hybrids (specialty quality). Robusta, Caturra and HDT scored the lowest (77.04, 78.50 and 79.96 respectively), scores that were below specialty quality.

Sensory data was subjected to principle component analysis (PCA). PCA results indicated that the first two principle components explained 95.62% (PC1 90.13% and PC2 5.49%) of the total variation (Figure 1). All the sensory attributes contributed almost equally to PC1 while body contributed the most to the variations observed in PC2 (Table 4). The genotypes Robusta, Caturra, HDT, SL28xUT3, N39xUT6 and N39 were placed in the negative side of PC1 while all the other genotypes were placed in the positive side of PC1. The genotypes placed in the negative side of PC1 were characterized by having lower beverage quality (Figure 1).

Diversity of coffee genotypes as determined by biochemical components

The coffee genotypes showed significant ($p<0.05$) differences in the levels of caffeine, oil and sucrose while CGA and trigonelline did not show significant differences among the genotypes (Table 5). Robusta recorded the highest percentage of caffeine content (2.39%). All the interspecific F_1 Arabusta hybrids recorded average to high caffeine content ranging from 1.98 to 2.25% except SL28 x UT8 and SL28 x UT6 (which recorded caffeine content of 1.53 and 1.77% respectively). Arabica genotypes recorded low caffeine content among all the genotypes with SL34 recording the lowest at 1.09% and Caturra with the highest at 1.65%. All the Arabica genotypes recorded significantly ($p<0.05$) higher oil contents than Robusta and the interspecific F_1 Arabusta hybrids except SL28 x UT8 whose oil content was similar to Arabica. Robusta recorded the lowest oil content of 13.39%. Similarly, Robusta showed the lowest content of sucrose (5.75%) while UT6 x SL34 accession recorded the highest amount (9.99%).

The data of the five biochemical components analyzed for the 15 coffee genotypes was subjected to principle component analysis (PCA). The first three principle components explained 84.870% (38.86, 25.59 and 20.43%) of the total variation respectively (Table 6). Six coffee genotypes, (SL34, SL28, Caturra, N39, UT8 x SL28 and HDT) were placed in the positive side of PCA graph while the other nine genotypes Robusta, SL28 x UT3, SL34 x UT6, Caturra x UT6, SL34 x UT8, SL28 x UT6, Caturra x UT8, N39 x UT6, and N39 x UT8 were placed in the negative side of the PCA graph. The genotypes in the negative side of the PC plot were characterized by high caffeine content while those in the positive were characterized by high oil contents (Figure 2). The biochemical components contributed differently to the variations observed in PC1, PC2 and PC3 (Table 6).

Correlation coefficients between sensory and biochemical variables of the coffee genotypes

The results indicated significant ($p<0.001$) positive correlations among all the cup quality traits (Table 7). Sucrose showed significant ($P<0.05$) correlations with fragrance flavour, aftertaste and overall. Trigonelline showed a significant negative correlation with body and

Table 5. Mean caffeine, trigonelline, oil, sucrose and total chlorogenic acids (CGA) % dry weight basis (DWB) for 15 coffee genotypes in this study.

Genotype	Biochemical components				
	Caffeine	Trigonelline	Oil	CGA	Sucrose
Robusta	2.4[a]	1.2[a]	13.4b	4.7[a]	5.8[e]
SL34x UT8	2.2[b]	1.2[a]	15.2[b]	5.47[a]	7.95[cd]
SL28 xUT3	2.2[b]	1.6[a]	14.5[b]	5.55[a]	9.91[ab]
Caturra x UT8	2.1[b]	1.05[a]	13.9[b]	5.52[a]	8.96[abc]
Caturra x UT6	2.0[b]	1.15[a]	14.7[b]	5.36[a]	6.92[d]
UT6 x N39	2.0[b]	1.38[a]	14.56[b]	5.25[a]	7.47[d]
UT6 x SL34	2.0[b]	1.16[a]	14.17[b]	4.96[a]	9.99[a]
UT8 x N39	2.0[b]	1.18[a]	15.25[b]	5.90[a]	8.94[abc]
UT6 x SL28	1.8[c]	1.14[a]	14.32[b]	5.74[a]	8.67[bc]
Caturra	1.6[cd]	1.46[a]	19.43[a]	5.13[a]	7.61[d]
UT8 x SL28	1.5[de]	1.44[a]	18.26[a]	5.01[a]	8.71[bc]
N39	1.4[ef]	1.32[a]	18.13[a]	5.65[a]	7.44[d]
SL28	1.2[fg]	1.19[a]	18.53[a]	5.22[a]	8.67[bc]
HDT	1.1[g]	1.19[a]	18.49[a]	5.10[a]	7.16[d]
SL34	1.1[g]	1.13[a]	18.27[a]	4.96[a]	9.18[abc]
LSD (P<0.05)	0.054	0.422	0.502	0.805	0.746
P-value	< 0.0001	0.400NS	< 0.0001	0.200NS	< 0.0001

Means within a column not sharing a letter are significantly different at P<0.05.

Table 6. The first three principle components (PC) of the five biochemical variables.

Variable	PC1	PC2	PC3
Caffeine	-0.660	-0.132	0.305
Trigonelline	0.152	0.200	0.936
Oil	0.693	0.067	0.026
CGA	-0.246	0.626	-0.163
Sucrose	-0.014	0.739	-0.063
Eigenvalue	1.943	1.279	1.021
Variability (%)	38.857	25.586	20.428
Cumulative (%)	38.857	64.442	84.870

CGA: Total chlorogenic acids.

caffeine.

DISCUSSION

The results indicated significant (p<0.05) variation among the 15 coffee genotypes in this study for sensory attributes. This is an indication of high genetic variation among the genotypes for all sensory traits. This was in agreement with previous findings reported by Dessalegn et al. (2008), Kathurima et al. (2009), Kathurima et al. (2010) and Tessema et al. (2011). This result partly agrees with Gichimu et al. (2012) who reported significant (p<0.05) variations in all the sensory traits except body in 34 Ruiru 11 sibs. Coffees graded according to the Specialty Coffee Association of America (SCAA) grading system should, receive more than 80 points in total score to qualify as specialty (Lingle, 2001). All the Arabusta hybrids, SL28, SL34 and N39 attained an overall sensory score of above 80 and were therefore of specialty grade. This was in agreement with Owuor (1988), who reported that introgessed lines were found to produce good beverage quality similar to non-introgressed standards. Robusta, HDT and Caturra attained 77.71, 79.96 and 78.50 points respectively that were below the specialty grade. Gichimu et al. (2012) reported a total mean of 82 points for all the sensory traits for Ruiru 11 sibs. Although the intogressed genes in Arabusta hybrids did affect the beverage quality, undesirable effect (bitterness) often associated with introgressed segments (Bertand et al., 2003) from Robusta genome, was picked out by the judges among the hybrids.

Van der Vossen (1985) recommended overall standard as the best cup quality selection trait due to its high heritability. On the other hand, based on correlation, repeatability and sensitivity analyses, Agwanda (1999) recommended flavour rating as the best selection criterion for genetic improvement of cup quality in Arabica coffee. However, this study showed that all the sensory variables analyzed in this study using trained panel of tasters were important in determining the overall quality of a coffee.

The 15 coffee genotypes recorded highly significant (p<0.05) differences for caffeine, oils and sucrose while

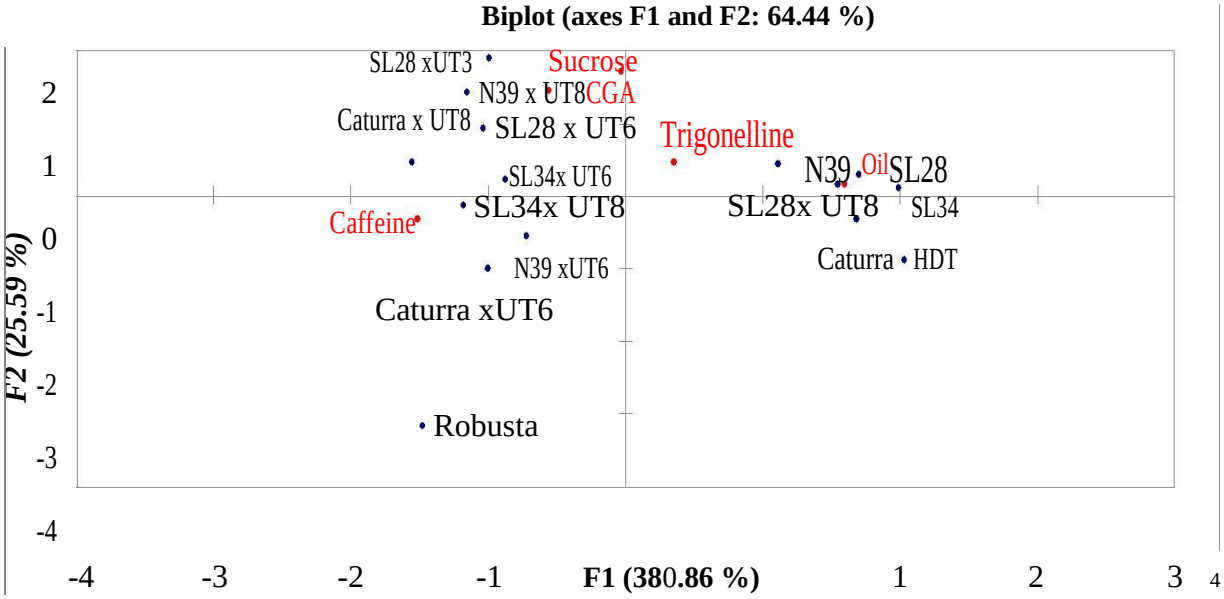

Figure 2. Principle component (PC) analysis plot of first two principle components, illustrating relationship among the coffee genotypes assessed for biochemical components.

Table 7. Correlation coefficients between sensory and biochemical variables of the coffee genotypes.

Variable	Fragrance	Flavour	Aftertaste	Acidity	Body	Balance	Overall	Caffeine	Trigonelline	Oil	CGA
Flavour	0.92**										
Aftertaste	0.90**	0.97**									
Acidity	0.88**	0.97**	0.97**								
Body	0.68**	0.80**	0.79**	0.76**							
Balance	0.86**	0.95**	0.91**	0.95**	0.69**						
Overall	0.90**	0.96**	0.96**	0.98**	0.74**	0.96**					
Caffeine	-0.08	-0.3	-0.28	-0.42	-0.19	-0.39	-0.36				
Trigonelline	-0.34	-0.39	-0.34	-0.33	-0.58*	-0.43	-0.31	0.05			
Oil	-0.09	0.05	0.09	0.25	0.14	0.2	0.21	-0.86**	0.25		
CGA	0.24	0.27	0.23	0.23	0.27	0.24	0.29	0.14	-0.03	-0.19	
Sucrose	0.64*	0.54*	0.58*	0.53*	0.29	0.48	0.54*	0.1	0.08	-0.03	0.29

**Correlation significant at the 0.01 level; *Correlation significant at the 0.05 level.

trigonelline and CGA did not show significant differences. This result was in agreement with Tessema et al. (2011) and in partial agreement with Anthony et al. (1993) and Kathurima et al. (2010). Anthony et al. (1993), studied biochemical diversity on genus *Coffea* L. using HPLC analyses to determine the contents of caffeine and chlorogenic acids (CGA) and reported highly significant differences for caffeine content within species variation. This study indicated significant variations within Arabica and Arabusta hybrids for caffeine content.

Kathurima et al. (2010) reported genotype effect factors on the levels of total chlorogenic acids (CGA) and caffeine but no significant ($p<0.05$) differences were observed in the levels of trigonelline and oils among the composite Ruiru 11 hybrids. This partly agrees with the result from this study as there was significant variation among the interspecific F_1 Arabusta hybrids for caffeine, oils and sucrose. This result is also in agreement with Tessema et al. (2011) who studied variability and association of biochemical attributes in *C. arabica* germplasm collection and reported that the performance of all the study genotypes were highly significant ($p < 0.01$) for caffeine and oils.

Correlations between coffee cup quality and some chemical attributes may be used as an additional tool for coffee quality evaluation (Farah et al., 2006). There were positive significant correlations between all the sensory characteristics. Sucrose showed significant ($P<0.05$) correlations with fragrance, flavour, aftertaste and overall. Trigonelline showed a significant negative correlation with

body and caffeine. The content and nature of sugars in the green coffee beans is important in the development of flavour and pigmentation during roasting. Sucrose is the main contributor of reducing sugars which are implicated in Maillard reactions occurring during the roasting process (Grosch, 2001). As the most abundant, sucrose acts as aroma precursors that affect both taste and aroma of the beverage (Maria et al., 1994). Higher sucrose contents in Arabica green beans have been shown to partially explain its better cup quality (Ky et al., 2001b). Trigonelline is a pyridine alkaloids that has been associated with flavor formation in coffee during roasting. Trigonelline negatively correlated with caffeine, that is, high caffeine values were accompanied by low trigonelline values and vice versa, indicating a close but competing linkage of the two pathways (Baumann, 2006).

Conclusion

The study demonstrated the existence of a high diversity in cup quality among all the genotypes studied. The interspecific F_1 Arabusta hybrids demonstrated variation for all the sensory attributes with a total mean score of >80 points, a Specialty Quality as per the SCAA green coffee classification chart. All the interspecific F_1 Arabusta hybrids produced results comparable to commercial varieties SL28 and SL34. The study also indicated significant diversity in biochemical traits among the genotypes for caffeine, oils and sucrose and no variation for CGA and trigonelline.

Recommendation

Future studies should be done to test the performance of the Arabusta hybrids in many locations with more variable climatic conditions and seasons.

Conflict of Interests

The authors did not declare any conflict of interests.

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