INFLUENCE OF GENOTYPE, LOCATION AND PROCESSING METHODS ON THE QUALITY OF COFFEE (*Coffea arabica L.*)

M.Sc. THESIS

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STATEMENT OF THE AUTOR

I declare that this thesis, submitted in partial fulfillment of the requirement for MSc. Degree in plant science(Horticulture) to Hawassa University, is my own original work and has not been submitted to any institution any where for the award of any academic degree or diploma. All sources of materials and financial support used for this thesis work have been duly acknowledged. This thesis can be deposited in the university library to be made available to readers or borrowers come to pass under rules of the university library. Brief quotation from this thesis is allowable without special permission provided that accurate acknowledgement of source is made. In all other instances, however, permission must be obtained from the author.

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Place: Hawassa University

Date of submission: ______________

LIST OF ABBREVIATIONS

ASIC	Association Scientifique Internationale du Café’
CLU	Coffee Liquoring Unite
CENICAFE	Center no Nacional de Investigaciones de Cafe’ (Colombia)
CRD	Completely Randomized Design
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GNP	Gross National Product
ILRI	International Livestock Research Institute
IPO	Intellectual Property Office
IPMS	Improving Productivity and Marketing System
ISO	International Standard Organization
ITC	International Trade Center
JARC	Jimma Agriculture Research Center
MoARD	Ministry of Agriculture and Rural Development
ORSTOM	Institute Francais de Recherche Scientifique pour le De’veloppement En Coope’ration
PA	Peasant Administrative
SAS	Statically Analysis Software
SNNPRS	South Nation Nationalities and Peoples’ Regional State

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INFLUENCE OF GENOTYPE AND PROCESSING METOD ON THE QUALITY OF SIDAMA AND YIRGACHEFFEE COFFEE

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ABSTRACT

Despite the wealth of genetic diversity and wide climate, the yield and quality of Ethiopian coffee is below expectations, largely due to the predominant use of traditional production and processing methods. To this end, this study was undertaken with the focus on identifying suitable coffee genotypes with best quality attributes for the Sidama and Yirgacheffee type types and to study the effect of environment and processing method on their inherent quality. For this, 17 coffee accessions (14 accessions plus 3 landraces) were examined for physical and sensory attributes with factorial complet randomized desiggn. The red ripe cherries were hand picked from three study sites (Awada, Korke, and Konga) and evaluated under three processing methods (wet, semi-washed and sun drying). Besides climatic variables, soil samples of the study sites were analyzed for some physico-chemical properties and associated with the relevant coffee quality parameters. The results depicted significant variations due to locations, coffee genotypes, and processing methods at ($P \leq 0.05$) for most coffee quality traits. In addition, the interaction effects between the treatments were significant at ($P \leq 0.05$). Accordingly, such coffee genotypes as 9744, 9718, and the local landrace were superior at Awada; while, 9718, 979 and 85294 were the best Sidama types at Korke. Similarly, among the Yirgacheffee types 9744, 9718, and 9728 showed the best results for the physical, cup quality and character. With regard to processing methods, the wet method significantly ($P \leq 0.05$) improved coffee quality over the other practices and resulted in better over all quality, citric, and spicy taste for Sidama and citric floral with more acidity for the Yirgacheffee coffees. Dry processed coffee had more viscous and mouth full body, flavor and creamy test. The semi-washed coffee had intermediary result. Coffee quality improvement due to processing techniques followed the descending order of washed, semi-washed and sun dried, indicating the alternative options to be practiced under specific conditions. With regard to treatment interaction effects, coffee genotypes were noted to be site specific in terms of their quality, largely due to adaptation to the prevailing climatic and soil conditions. The combined effect of genotype and processing method was also significant at ($P \leq 0.05$), perhaps indicating the existing genetic diversity in bean size and compositions. From the present findings, it can concluded that sustainable production of market oriented best quality coffee types require, among others, careful selection of suitable coffee types, site conditions and post-harvest handling and processing techniques. However, further studies should be progressed mainly in the areas of evaluating and developing suitable landraces for each agro-ecology using other chemical compounds including caffeine. Mapping quality profile of Sidama and Yirgacheffee coffees with the view to target niche markets also remain for future investigations.

1 Introduction

Coffee (*Coffea arabica L.*) is the most important agricultural commodity and beverage enjoyed throughout the world and worth up to US $ 14 billion annually for producing country, and more than 18 countries, including Ethiopia, cultivate coffee, which is exported as raw, roasted or soluble product to more than 165 countries worldwide providing a livelihood for an estimate of some 100 million people around the world (ICO, 2001). Many countries are involved in coffee production, trade, communication and it is estimated that, more than 125 countries export and re-export coffee products. In addition, more than 50 developing countries are earning 25 % of their foreign exchange from coffee (CTA, 1999; ITC, 2002).

In Ethiopia, about 25 % of the total populations of the country are dependent on production, processing, distribution and export of coffee. It accounts for more than 25 % of the GNP, 40 % of the total export earnings, absorbing 25 % of the employment opportunity for both rural and urban dwellers, and 10 % of the total government revenue GDP (CTA, 1999; MoARD, 2008).

Coffee grows at various altitudes, ranging from 550 to 2750 meters above sea level (m a.s.l). However, Arabica is best thrives and produced between altitudes of 1300 and 1800 m a.s.l, with annual rainfall amount ranging from 1500 to 2500 mm with an ideal minimum and maximum air temperatures of 15 and 25 ^{0}C, respectively. This prevails in most of the countries coffee growing areas. But, for extremes and some cases, it grows up to 550 m a.s.l (like Bebeka) and in areas where annual rainfall ranges from 1000 to 2000 mm (CTA, 1999; Bayetta, 2001).

The total area covered by coffee in Ethiopia is about 600,000 hectares, with a total of annual coffee production ranges from 300,000-350,000 tones, which is about 600 kg ha^{-1}. Out of this, more than 90 % of the coffee is produced by small-scale subsistent farmers, while the remaining comes from private and government owned large-scale farmers (Workfes and Kassu, 2000; MoARD, 2008). In southern regions, about 50 districts are producing coffee and 235,000 ha of land is devoted to coffee production with the annual production of 120000-140000 tons, of which 70,000 to 100,000 tons are supplied to the central market .The washed and sun dried coffees account for 46 % and 54 % making the share of washed coffee to 70 % of the countrys export (Simayeh et al., 2008).

The genus *Coffea* consist more than one hundred different species. The species vary in terms of chemical composition (Clifford, 1985). And within *C. arabica* the variability in quality takes a particular pattern with mutants presenting specific quality attributes such as caturra (dwarf, high productivity sometimes linked to a drop in quality) or maragogype (very large beans low productivity but highly priced or the marked). In addition, some mutants have been identified, especially regarding low caffeine contents, such as *C. arabica* variety Laurina (0.6 % dm) and more recently, in Brazil, an Ethiopia origin with traces of caffeine (Silvarolla et al., 2004).

According to the current context of over production and low price of coffee market, improvement and valorization of coffee quality could provide the coffee chain with a new impetus. In this context, one can easily understand that the efficiency of integration of coffee

quality as main target in breeding program as opposed to previous status secondary selection criteria (Van der Vossen, 1985). Since coffee becomes today's one of the leading marketable commodity next to oil, qualified professionals are seriously investigating the quality of coffees, because they know that the district flavors and character of coffee to safeguard consumers demand and interest beside today's market challenge. For example, the specialty markets of coffee are paying the premium price for the specialty preparation of coffee keeping its original types. In this regard, quality is a must that one can observe as a raw (green appearance), cup quality (smell the aroma, evaluate the body and perceive taste, flavor) and overall quality standard. Indeed, assessment of organoleptic quality is an extremely demanding exercise (Leroy et al., 2006). That is, it is obviously important knowing the geographic and specific botanical origin of coffee for the purpose of fair international trade. This is because the origin can be used either alone or in blend imparts to the finished products on its unique sensory characteristics. Furthermore, premium price has been paid for certain origins, which also often stated on the label of coffee product (Prodoliet, 2004).

Based on the extreme demand for coffee quality to the character of those origins (types):Yirgacheffee and Sidama brands are now internationally recognized and registered as property right to Ethiopia with their distinct character/flavor and taste (IPO, 2008). In addition, to expand export market and for sustainable utilization of the immense genetic diversity, keeping the coffee quality is a serious issue to compete and sustain in the competitive market (IPO, 2008; Dessie et al., 2008).

In Ethiopia, the southern region is the second largest producer and supplier of arabica coffee. Simayehu et al. (2008) reported that coffee is the most important crop in the regions sharing about 45% in the national market. Among these, Sidama and Gedeo zones represent the major coffee growing and densely populated areas where different *Coffea arabica* landraces are known to exist (Taye et al., 2004). The land races known by different vernacular names (Kurmie, Woliso and Deiga). These coffee types have their own distinct growth characters and quality used to distinguish them, though there is little information available to use the coffee resources in the region.

Ethiopia exports its coffee based on their areas of origin (type), which are known for their own distinct quality and agronomic characters (MoARD, 2008). The development of local landraces for each locality largely based on their yield performance and resistance to major diseases like coffee berry disease (CBD) and quality would help to reduce quality adulteration of the inherent quality of known coffees in the country. Besides genetic and environmental factors, the range of cares taken from field to cupping can affect coffee quality. In this regard, research information on the influence of environmental factors such as soil, altitude, rainfall, and temperature as well as field management on coffee quality is scanty in most coffee growing regions of the country. Above all, the influence of harvesting, post-harvest processing and handling methods on coffee quality has been little studied in Yirgacheffe and Sidama areas. Therefore, the present study was carried out with the following specific objectives:

1. To identify suitable coffee genotypes with best quality attributes for each locality in Sidama and Yirgacheffe,

2. To study the effect of environmental factors on green and cup quality of Yirgacheffe and Sidama coffee genotypes

3. To evaluate the effect of different coffee processing methods on quality of the different Sidama and Yirgacheffe coffee types.

2 Literature Review

2.1 Botanical classification and characteristics

Coffee (*Coffea arabica* L.) is the major species of the family Rubiaceae, which includes some 400 genera and 500 species, mostly trees and shrubs, mainly found in the lower regions of the tropical rainforest (Graff, 1986). The first botanical description of a coffee tree, under the name *Jasminum arabicanum*, was made in 1713 by A. de jussieu, who studied a single plant originating from the botanic garden of Amsterdam (Graff, 1986;Wintgens, 2004). However, according to Linnaeus (1737) in Clifford and Wilson (1985), classified it as a separate genus *Coffea* with the then only one known species *C. arabica.*

According to the study made by botanists and geneticists due to the existence of diverse variability, the natural coffee populations considered as *Coffea arabica*, *C. canephora, C. stenophylla, C. tnguebariae,* and *C. liberica* (Charier and Berthaud, 1985). But from recent commercial importance of green coffee market and production, the two species of *Coffea arabica* and *Coffea canephora* are dominating world coffee production and marketing (Van der Vossen, 1985).

All botanists, who have explored the forests in the southwestern highlands of Ethiopia reported that the country is the center of diversity of *C. arabica* (Sylvain, 1955; Meyer, 1965; Clifford and Wilson, 1985). It is known for the longest time and the widest spread species throughout the world, and it is evergreen, often multi stemmed shrub about 8 to 10m tall. *C. arabica* is tetraploid (2n = 44) and is self-fertile (Charrier and Berthaud, 1985). Some natural cross-pollination occurs, effected by insects and wind. The ovary develops into a globular or

oval drupe, normally containing two seeds. It has a length of 14-18 mm and a diameter of 10-15 mm. It is usually called a cherry or a berry, although botanically not correctly so. The fruits take 7 to 9 months to mature. When mature, the skin is red (for some verities yellow), covering a slipper sweet and mucilaginous pulp. Inside the fruit, the two seeds (coffee beans) lie with their flat sides together. A loose, thin and yellowish skin (parchment), with a coating of thin slimy mucilage, covers each of the two coffee beans. Underneath that skin is a thin and closely fitting membranes tegument, known as the silver skin. The beans of *C. arabica* are 9-12 mm long, 6-7 mm wide and 3-4 mm thick, and weigh about 0.15-0.20 g. The average weight ratio of cherries to clean coffee beans is 5.5: 1 and clean coffee contains about 2200 beans per kilogram (Charrier and Berthaud, 1985; Clifford and Wilson, 1985; Graaff, 1986).

Coffea arabica has numerous botanical varieties, mutant and cultivars, which reflect the influence of environment. Among the many varieties, the most important ones are *C. arabica* var. typica and *C. arabica* var. bourbon. From these two important botanical varieties, a number of important mutants grown commercially and cultivars developed through selection and hybridization, which are now available in the different coffee growing countries (Van der Vossen, 1985). Arabica coffee performed over all other species because of its superior quality and continued to be the exclusive product of all coffee in the world, as it had been for more than 150 years until the end of the 19^{th} century. At the present time it still contributes about 75 % of the world coffee exports (Van der Vossen, 1985).

2.2 Coffee diversity

Ethiopia is the home of coffee (*Coffea arabica* L.) and there exists extremely diverse genetic reserves in the montane rainforests of southwest and south east of the country. About 5,800 Arabica coffee accessions are conserved as *ex-situ* and 25,000 ha of forest lands have been preserved as *in-situ* forest coffee conservation (MoARD, 2008; ICO, 2004).

Many important characteristics were identified in the Ethiopian Arabica coffee such as resistance to orange leaf rust (Wondimu, 1998) and coffee berry disease (Belachew et al., 2000). Variations in green bean caffeine, chlorogenic acid, sucrose and trigonelline contents variation were also observed (Silvarolla et al., 2000). There is also variation in the size and shape, bean size, shape, color and cup quality (Wondimu, 1998). The distinct attributes such as resistant to coffee diseases, adaptable to diverse environmental conditions (drought) also indicates the existence of diverse *C. arabica* genetic resources in the country. However, this gene pool is under serious threat mainly because of deforestation of its natural habitat for timber and food crop production and replacement of landraces by a few high yielding and diseases resistant improved varieties (Yigzaw, 2006). Thus, the Institute of Biodiversity Conservation (IBC) of Ethiopia preserved over 4500 accessions in the field as coffee gene bank on 115 ha land in Keffa, South Western part of Ethiopia (ITC, 2002).

This is substantiated by the fact that within Harerghe region, including the major coffee producing districts such as Habro, Cherchar, Wobera, Gara Muleta, Harer zuria and Gursum, which are know for production of best quality coffee. There is high variability for yield and other characters. Furthermore, survey results indicated the presence of considerable variation

among Harar coffee types such as Abadiro, Kubania, Shimbure, Buna qalla (Mesfin and Bayetta ,2003)

According to the evaluation made with RAPDS on the genetic diversity of 50 wild and semi-wild accessions of *Coffea arabica* L. germplasms collections gathered by FAO and ORSTONS mission to Ethiopia, and maintained in Colombia by CENICAFE, a larger polymorphism is present in the Colombian replica of FAO Ethiopian coffee germplasm collection than previously reported (Bayetta Bellachew et al., 2000; Cristancho et al., 2004). Extreme diversity was exhibited by coffee accessions gathered in the Kaffa province (Cristancho et al., 2004). Interestingly, commercial accessions caturra and Bourbon (N-100) showed a high degree of genetic variability between them. This is surprising since caturra is dwarf mutant of the cultivar Bourbon. Hence, according to Cristancho et al. (2004), this can be used to improve the popular commercial varieties such as caturra and with the help of more elaborate molecular markers new cultivars can also be generated by introgression of wild alleles oriented towards disease resistance and specialty market.

The ex-plantation for the genotypes for the same geographical origin falling into different clusters can be found in the wild genetic divergence in the features created within each geographical zone through selection and genetic drift. Similarly, Bayetta (2001) reported that morphological variation is more important than variation in geographical origin as an indicator of genetic diversity in Ethiopian coffee. The work done by Seyoum et al. (2004) on eighty-one accessions of the Ethiopian coffee germplasm also revealed the presence of trait diversity that can be exploited in the genetic improvement of the crop through hybridization and selection.

The existence of vast genetic variability in *Coffea arabica* accessions of Ethiopia creates the opportunity to maintain or develop coffee cultivars with distinct raw and cup characters. For instance, an evaluation of the caffeine content of beans from 99 progenies showed related intra- and inter- progeny variability. In 68 progenies from Kaffa region had caffeine values in the range of 0.46-2.52 % (mean 1.18 %), and 22 progenies from Illubabour region contained caffeine ranging from 0.42 to 2.90 % (mean 1.10 %). Thus, this variability can be exploited in a breeding program aimed at producing beans with low caffeine content (Silvarolla et al., 2000) and this should be among the high priority areas to be studied in Ethiopia.

2.3 Coffee adaptation

Adaptation of coffee landraces along topographic gradient has been studied by Taye et al. (2004) in Sidama and Gedeo zones, representing the major coffee growing and densely populated areas in the Southern Ethiopia with the respective density of 451 and 590 persons per km^2 (CSAE, 1998). The land is irregular as mountains, valleys, steep and gentle slope and almost flat land characterize it. According to the report, arabica coffee landraces of these areas were known by different vernacular names (kurmie, wolisho, and deiga) that can be broadly grouped into three morphological classes. Kurmie (compact type) has small leaves, fruits, compact canopy and short height. On the other hand, wolisho (open types) has the longest leaves, fruit, bigger canopies volume, stiff stem and tallest height. Deiga (intermediate types) lies between the two classes. The study also indicates the association between plant parameters and site factors. That is, the most recurring local coffee was the diega type in the high altitude areas of Gedeo zone where there was higher extinction rate of open wolisho and

compact kurmie classes (Taye et al., 2004). In addition, farmers also reported variations among these coffee landraces in yield performance, disease resistance, and quality attributes, which requires detail studies.

2.4 Coffee quality

Quality is a trait difficult to define. According to any dictionary, it is an inherent or distinguishing characteristic. The International Organization for Standardization (ISO) describes quality as the ability of a set of inherent characteristics of product, system or process to fulfill requirement of customers and other interested parties (ISO, 2000). These inherent characteristics can be called "attributes".

There are different views of expressing quality. ITC (2002) defines that the quality of a parcel of coffee comes from combination of the botanical variety, topographical conditions, weather conditions, and the care taken during growing, harvesting, storage, export preparation and transport. On the other hand, for coffee, the definition of quality and the attributes considered have probably evolved through the centuries. Now days, according to Lorey et al. (2006), this definition varies along the production to consumer chain:

- At the farmer level: coffee quality is combination of production level, price and easiness of culture;
- At the exporter or importer level: coffee quality is linked to bean size, lack of defects, regularity of provisioning, tonnage available, physical characteristics and price;

- At the roaster level: coffee qualities depend on moisture content, stability of the characteristics, origin, price, biochemical compounds and organoleptic quality. It should be noted that each consumer market or country may define its own organoleptic qualities;
- At the consumer level: coffee quality deal with price, taste and flavor, effect on health and alertness, geographical origin, environmental and sociological aspects (organic coffee, fair trade, etc) (Lorey et al., 2006).

2.4.1 Physical and organoleptic qualities

2.4.1.1 Moisture content

The moisture content of coffee bean is an important attribute and indicator of quality. High moisture content of the beans is a loose sensorial defect. If coffee beans are too wet (above 12.5 % moisture), can mould easily during storage. In addition, if the beans are too dry (below 8 % moisture) they loose flavor. The moisture content can influence the way coffee roast and the lost of weight during roasting. Green coffee with low moisture contents tend to roast faster than those with high moisture content (Leroy et al., 2006; ITC, 2002). Hence, the ICO resolution 407 recommends that coffee should not be exported when outside of these limits as assessed by the ISO 6673 method (ISO, 2000).

2.4.1.2 Physical quality

The International Coffee Organization (ICO, 2001) implemented a Coffee Quality Improvement Program (CQIP) with recommendation to exporting countries. It is not recommended that coffee can be exported with the following characteristics: for arabica in excess of 86 defects per 300 g sample (New York green coffee classification Brazilian method, or equivalent) and ISO (2004b) has also established a standard (ISO 10470) that describe defects as:

- Foreign material of non coffee origin;
- Foreign materials of non bean origin, such as pieces of parchment or husks;
- Abnormal beans for shape regularity/integrity;
- Abnormal beans for visual appearance, such as black beans;
- Abnormal beans for taste of the cup after proper roasting and brewing.

Bean size, which is usually determined by screening, is of particular importance to roasters since bean of the same size would be expected to roast uniformly. In addition, this size and shape difference of coffee beans where influenced by botanical variety and environmental growth circumstances (Sivetz and Dosrosiier, 1979; EAFCA, 2008). The internationally acceptable screen unit is 1/64 of an inch. For example, beans of screen 18 refer to those that retained by a sieve with aperture (holes) of diameter 18/64 of an inch (ISO, 2000; EAFCA, 2008).

2.4.1.3 Organoleptic quality

When assessing organoleptic quality, one has to take into account that consumers have a specific taste according to their nationality, which leads to an unreliable definition of organoleptic quality (Wintgens, 2004; Leroy et al., 2006). In addition, organoleptic characteristics must be stable, especially for the roaster and the consumer. The smell of the ground-roasted coffee before water added sometimes called fragrance. Then, one can smell the aroma, evaluate the body and perceive taste and flavors. Organoleptic quality measurement relies on overall or sensory evaluation (Leroy et al., 2006). Hence, assessment of coffee organoleptic quality is an extremely demanding exercise; indeed the flavor obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee (more than 800 in the roasted coffee) (Clifford and Wilson, 1985).

2.4.1.4 Health quality

The level of pesticide residues is usually low in coffee. *Ochratoxin* A (OTA) is a toxic *mycotoxin,* which is mainly due to mould development. In coffee, OTA produced by *Aspelgill nigher*, *A. carbonarius* and *A. ochraceus.* It is classified as possibly carcinogenic to humans (Eshetu and Girma, 2008).

2.4.2 Post harvest treatments and handling

2.4.2.1 Harvest and post harvest

It is widely agreed that traditional hand pricking and husbandry labor, as opposed to mechanical harvest, produce the best quality green coffee by decreasing the percentage of defects in coffee batches. Then, depending on the magnitude of care during harvesting and post harvesting processes, strong consequences on coffee quality can be observed (Barel and Jacquet, 1994).

Whether to achieve coffee quality by harvesting ripe cherries or harvesting a mixed product and complementing with proper post-harvest treatment is a cost benefit decision that coffee growers will have to face. If only ripe cherries are picked, the volume of quality of is higher, but harvesting cost is higher, too. If a mixed product is picked, the volumes of quality coffee are smaller, but harvesting costs fall. The decision facing the grower is whether the saving in harvesting cost offset the loss of income from less quality coffee. If they do, the grower should move away from selective hand picking and in to stripping and modern mechanical harvesting systems to maximize his profits (Wintgens, 2004).

Selective coffee picking is not the only way to ensure that quality in the tree is transferred to the cup. The fact is that selective picking is no more than an indicator that only sound, red, ripe coffee cherries should be used as raw material to produce the finest bean from which a perfect cup is brewed. Sound, fresh, red, ripe cherries may obtained from a variety of picking practices combined with processing techniques (Sivetz and Desrosier, 1979; Wintgens, 2004).

2.4.2.2 Wet processing

In the wet or washed coffee processing, the ripe fruit is squeezed in pulping, which is the key operation and difference from the dry process in which the soft pulpy part of the cherry together with the skin is 'turn off' as soon as possible (Clark, 1985). The machine removes most of the soft outer pulp or fibrous fruit flesh, leaving a slippery exposed layer of mucilage. Since the layer of mucilage cannot be readily dispersed in water, one of several methods leaving the clean parchment layer removes it. And the product is called washed coffee, because the mucilage is finally removed by washing with water (Sivetz and Desrosier, 1979). The parchment (pergamino) can finally be hulled to provide the dry green been (Clark, 1985).

2.4.2.3 Dry processing

This is a natural process and is the simplest and the harvested cherries classified then are dried in their entirety, most usually in the sun (Clark, 1985) or the fruit is allowed to remain on the tree past the full ripe stage and is partially dried before harvesting (Sivetz and Desrosier, 1979). The dried coffee cherry when at about 12 percent moisture is then subjected to a milling operation (or 'hulling' or rather 'dehusking') to separate out the green bean (Clark, 1985).

In general, washed coffee carefully prepared and handled, is clean in flavor and free from undesirable element (Sivetz and Desrosier, 1979). Wet processed Arabica is aromatic with fine acidity and some astringency, while dry processed Arabica is less aromatic but with

greater body (Clifford, 1985). The use of ‘under water fermentation as opposed to ‘dry’ accentuates the formation of acids (Clark, 1985). Natural coffee, since it is always dried in contact with its mucilage, has a better body as due to this fact under ideal condition natural coffee may be of excellent quality, clean testing and full bodied and, while different, fully as desirable as washed coffee.

2.4.3 Green coffee storage

Storage is one of the most important and crucial stage in processing of any agricultural commodity. In case of coffee storage, the goal is to achieve and maintain its commercial value as long as possible by preserving the integrity of the bean with all its characteristics.

The need for adequate storage is crucial since coffee beans are living entities in which their viability depends largely on storage condition and food safety has now become an extremely important issue since the effects of toxic substances, which would develop during storage, can cause significant harm to human health. In addition, although coffee does not have a great nutritional value, its price is based on its sensorial value. This is dedicated aspect, which can easily be affected if storage is not adequate. Besides this, due to the inherent imbalance between supply and demand in the coffee market, it is some times necessary to store coffee for long period of time in which the length of storage affects the quality of coffee.

2.4.3.1 Bean physiology and environmental influence

Intrinsic physiology

Coffee beans or seeds, just like leaves , stems and roots are vegetative products. They retain all characteristics and activities of a living being; including respiration and transpiration, among other elements, regardless of weather, they are stored as dry cherry, parchment or green coffee. The impact of respiration on the bean deterioration is that, every 24 hour, an average of 4.4mg of CO_2 are produced by 100g of coffee beans and, the 96 cal of heat produced by 44mg of CO_2 will raise the temperature by 0.25^{o}C. Consequently, during storage, the temperature will increase sequentially. The deterioration cause by this effect is incrementally cyclic. That is a high respiration rate, combined with the generation of heat, causes a loss of weight and dry material in the bean as well as the decomposition of components, like fats, which play an important role in the aroma (Sivetz and Desrosier, 1979).

Viability

A bean that can germinate is known as a viable bean. Viability depends on the condtion of the bean itself as well as on storage condition. Physical damage caused during harvesting or processing has a considerable effect on the bean. A high metabolic or respiratory aciticvity may also significantly affect seed viability. That is there is a relation between the O_2 absorption by the seed and its germination capability, measured in the form of the coefficient of $C0_2$ produced/volume of O_2 absorbed, which reaches high values with bean deterioration (Wintgens, 2004).

Moisture content and RH

Humidity is the factor, which has the highest impact on the speed at which coffee bean deteriorates. Even if beans have been stored with a low moisture content the humidity factor is still very active because they are hygroscopic and tend to balance their moisture content with their immediate surroundings known as " moisture balance ". It is generally recognized that the ideal coffee moisture content for the preservation of coffee is 12 % for Arabica and 13 % for Robusta. Beans with moisture content lower than 9 % may be irreversibly damaged in color, as well as in their cup test and consistency, which means that it is not worth reducing the moisture content to such a low level when drying (Sivetz and Desrosier, 1979).

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A RH level of 75 % corresponds to a moisture content in the bean of 15-16 %. According to the Henderson balance, this is the critical level for fungi formation. As the result, the RH level should be kept below 60 % because one of the most obvious effects of a high RH level, in combination with temperature variations, is the condensation of water, which, in tern, contributes to the proliferation of fungi and insects (Ramaiah, 1985).

There is a genuine concern on the part of carriers, exporters and importers with respect to the loss of moisture and weight. Since the loss of humidity during storage or transportation also results in a loss of weight of the coffee and consequently in the profit margin, whether it is due to the commercial weight franchise negotiation, which represents 0.5-1.0 % or to the storage losses, which are reflected on the total manufacturing losses of any roaster or solubilizer. Under ideal condition, the storage losses, in general, should not exceed 1 % on an annual basis (Wintgens, 2004).

Temperature

Temperature is the most important element, which affects coffee bean quality. The higher the temperature, the higher the metabolic activity of the seed. Coffee with moisture content as low as 11 % loss their quality after 6 months under a temperature of 35^{o}C. On the other hand, a coffee with moisture content above 15 % will maintain its quality at temperature as low as 10^{o}C. Coffee needs to be maintained at low temperature to reduce its metabolism and respiration. According to the calculation made by Sivetz and Desrosier (1979), reveal that 8000 stored bags of coffee generate a heat of 210400 BTU. This highlights the obvious need for ventilation in coffee warehouses and storage premises.

Altitude

The altitude factor related with the most important factors of moisture, RH and tmprature. Storage life will be shorter at lower altitude, i.e. approximately 3 months at 600 m. Where as altitude above 1400m natural shelf life can be of 8 months. Inevitably, this means that exporters and industrialists prefer high altitude locations for coffee storage (Wintgens, 2004).

Duration

The longer the storage time, the less the preservation of the product characteristics. The generally accepted time for green coffee storage is, under normal conditions, one year. Coffee stored more than one year affects quality (Wintgens, 2004).

2.4.3.2 Main storage problem

Coffee is susceptible to attacks by pests' and fungi. The damage caused to coffee by these two parasites can be extremely serious both from the financial point of view and with regard to the incidence on consumers' health. This does not only involve the pesticide residue level in the bean, but also the level of toxins, which may affect human beings. As a result, many companies engaged in coffee processing, storage and transportation have set up process control programs. Similar control systems should be set up to guarantee quality through traceability, good storage practice, identification of critical control points and quality monitoring systems (Kader, 1992).

Pests

Insects are one of the most important problems in coffee storage. Damage caused by insects can be lethal to the point that it may destroy the total value of a stored lot. A three-year study has revealed that 71 % of the cases, damage appeared in imports. Some of the insects that affect coffee during storage are coffee berry borer, an important pest in coffee in its storage because its biological cycle enables it to continue feeding on the beans for months, it can even cause total loss of the infested beans, which leads to the drop of their commercial value. And coffee bean weevil, one of the most harmful as it even attacks dry coffee cherries. Its larvae develop in environments with a high RH, 80 %, and temperature of 25^{o}C or more, conditions which generally prevail in tropical and sub tropical areas (Ramaiah, 1985; Wintgens, 2004).

Fungi

Fungi the most important storage problem. Fungi which chiefly attack coffee are *Aspergillus* spp. and *Penicillium verucosum*. The development of these fungi is favored when the moisture content of the bean is higher than 15 % and the RH above 75 %. Therefore, the level of moisture content should be maintained below 15 % and RH should be less than 70 %. In addition to their impact on the appearance, the aroma and flavor of coffee, fungi also produce toxic substances, which can be harmful when consumed. The most important of these are mycotoxins and ochratoxins, for which maximum tolerance levels have been ascertained (Ramaiah, 1985; Kader, 1992).

Quality impact

Stored coffee may present flavor damage, and the incidence of the existing damage may become more serious during storage. Potential damage caused during storage which affects cup flavor are baggy, moldy, earthy, onion (as a result of storage under humid condition in which prop ionic acid is generated which give " onion " flavor, old crop and contaminated. In addition of the impact on cup and green coffee color the defect due to bad storage can be infested bean and bleached beans (Lingle, 1986; Wintgens, 2004).

2.4.4 Pedo- climatic

Climate, altitude, and shade can play an important role through regulating temperature, availability of light and water during the ripening period. The distributions of rainfall and sunshine hour have a strong influence on flowering, bean expansion, and ripening. For instance, chlorogenic acids and fat content have been found to increase with elevation in *C.*

arabica. The role of soil types has been well studied and it is generally admitted that the most acidic coffee are grown on rich volcanic soils (Wintgens, 2004).

2.4.5 Genetic variation

The coffee genus includes more than one hundred different species between which a large variation in terms of chemical composition is observed (Clifford, 1985). Coffee produced from *C. arabica* is known to have a good quality. This characteristic is clearly established for classical varieties like Caturra, Mundo Novo, and other pure lines obtained from pedigree selection. Walyaro (1983) showed the presence of large inherent difference among genotypes for bean and cup quality attributes. Van der Vossen (1985) also observed in which variation for cup quality character among varieties and crosses of Arabica coffee.

Based on organoleptic evaluation, introgressed lines of Arabica were found to produce good beverage quality (BQ) that was similar to the non-introgressed standard (Owuor, 1988; Moreno et al., 1995; Lorey et al., 2006). SL 28 had big sized beans (46 %AA) and excellent cup quality, while catura and rume Sudan had small sized beans, lower cup quality and chemical content or the BQ (Van der Vossen, 1985).

The worlds' best quality coffees such as Harare, Limu, and Yirgacheffe (ITC, 2002) are produced in the eastern, south western and Southern parts of Ethiopia, respectively. Likewise, farmers, consumers and agricultural development agents reported the presence of considerable cup quality variation among different arabica coffee genotypes grown in north western Ethiopia (Yigzaw, 2006), thought not yet characterized for use and conservation in the region.

The most striking association and identification for coffee is its point of origin. The more one knows about the coffee's origin, the more confident one can be about its uniformity and properties. That is the respective details about the coffee's origin are, country of origin, state or region where grown, port of embarkation, the name of the mille exporter, the name of the grower, and the location of the grower's plantation (Sivetz and Desrosier, 1979).

2.5 Coffee quality assurance

The quality of a good cup of coffee, as experienced daily by millions of consumers, is not a matter of chance. It is the result of a quality assurance program implemented by all the key players of the coffee production to consumer chain (Prodolliet, 2004). Quality as it is defined by ISO (2000) and Dessie et al, (2008), in its more practical definition, can be the ability of a product to satisfy consumer's expectation. They mainly includes:

- Good sensory characteristics (eg. aroma, flavor, body, acidity)
- Absence of off-flavors (eg. mouldy, earthy, fermented, chemical)
- Safety (absence of contaminants, like pesticides, mycotoxins)
- Environmental aspect (eg. organic product).

Not all these quality characteristics are a matter of chance. They are the result of planned and systematic activities, prevented measures and precautions taken to ensure that the quality of coffee attained and maintained day after day. This is the meaning of quality assurance (Prodolliet, 2004). The quality of coffee can be predetermined by the genotype, the climatic conditions and the soil characteristics of the area in which it is grown. As a whole, a quality

assurance program has to be implemented by all the key players of the coffee production to consumer chain to achieve the common goal: quality and as a consequence, consumer satisfaction. Hence, quality assurance can be described from the level of a soluble coffee manufacturer, focusing on the main controls carried out from the reception of the raw material up to the release of the finished packed product

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2.5.1 Green coffee

The International Organization for Standardization (ISO) issued in 1992 guidelines to be used to describe green coffee for sale and purchase. The ISO 9116 standard requires the following information related to green coffee quality.

- The geographic origin country, region state, plantation
- The botanic origin (species, variety)
- The crop year
- The moisture content or loss in mass
- The total defect and foreign matter
- The content of insect damaged bean
- The bulk density
- The bean size.

Based on this, the soluble coffee manufacture buys green coffee according to those or similar guidelines specify for each point exactly what he wants. And he first control the green coffee arrived at his factory door (Prodolliet, 2004). The ISO 10470 standard defines defects as

"anything divergent from regular nicked sound green beans expected in a coffee lot" and classified them into five categories (ISO, 1993; Wintgens, 2004). These are:

- Field damaged bean or processed damaged bean (related to the coffee tree, the environment, attack by pests and diseases, and crop management)
- Harvest-damaged beans or processed damaged beans (caused by stress due to water or nutrient deficiencies, inadequate cultivation or harvesting practices, unsatisfactory primary processing)
- Defects occurring during processing (process damaged beans during like pulping, washing, drying, hulling, cleaning, etc.)
- Defects occurring during storage and
- Defects originated from coffee fruit (due to poor cleaning operation following de husking and dehulling).

This is the most important criterion of evaluation of green coffee, as their presences alter the final cup quality by generating off flavor.

2.5.2 Sensory evaluation

In the coffee industry, sensory evaluation is required to ascertain over all product quality along with the constancy of the quality over time and in varying process condition. The tool commonly put to use is a panel of assessors (professional cup-tasters) (Kauffman, 2005) who are trained, experienced tasters and have the vocabulary to describe the desirable and undesirable attributes of the beverage (Clifford and Wilson, 1985).

The coffee manufacturers (buyers) main concern is certainly to deliver to the consumer a product with high quality and regular in cup taste and aroma. Therefore, the purpose of checking the sensory profile of green coffee (at reception, after roasting) is to ensure the consistent quality of the finished product sensory evaluation is certainly the most reliable way to assess the quality of the raw material (ISO, 2001; Prodoliet, 2004). The basic element of the sensory evaluation of green coffee consists of:

- A spacious room, equipped with adequate illumination, a sample roaster, a grinder, a cupping table, cups and spoons.
- A methodology, describing precisely the roasting conditions, the particle size after grinding, the dosage of coffee in the brew, type and temperature of water used to prepare the brew, the way to taste (aroma assessment, removal of floating particles, sucking, use of reference samples), the type of tast, the number of cups tasted, etc.
- A vocabulary, defining all the sensory attributes to be evaluated and a well trained panel.

Cup quality, often referred as drinking quality or liquor quality, is an important attribute of coffee and acts as yardstick for price determination (Agwanda et al., 2003). For this, the assessment of sensory evaluation can be done organoleptically by panel of experienced coffee tasters (Van der Vossen, 1985) and is determined based on the level of acidity, body, and flavor of the brew (Raju et al., 1978; Walyaro, 1983; Morenu et al., 1995). Walyaro (1983) recommended this as a sufficiently reliable method for use as a basis of selection in quality improvement program. Similarly, Owuor (1988) observed close similarity among liquorers in

ranking various cup quality characteristics of the cultivar, indicating that any one panel could be relied on selection for cup quality.

Thus, coffee cupping is a technique used by cuppers to evaluate the flavor profile of a coffee, to understand minor differences between growing regions, to evaluate coffee for consistence and defects to subsequently make buying decision and to crate coffee blend (EAFCA, 2008). This consists of six steps, to evaluate a coffee's fragrance, aroma, nose, after taste, and body (Lingle, 1986).

Acidity is a primary coffee taste sensation created as the acids in the coffee combines with the sugar to increase the over all sweetness of the coffee (Petraco, 2000; EAFCA, 2008). High acid coffees have a sharp, pleasing snappy flavor, not biting (EAFCA, 2008) and gives better quality and more intense aroma to the beverage (Clifford, 1985). In general taste sense, it is the presence of the aliphatic acid group that gives brightness and best to coffee's flavor and is the under line reason why coffee with a high acidity (pH value: 4.8-5.1), which is the preferred range and typically sold at premium price (Lingle, 1986). This is a characteristic of high grown coffees such as Ethiopian Yirgacheffee, Sidamo, and Limu as well as coffees from Guatemala, Costa Rica, and Kenya (IPO, 2008; EAFCA, 2008).

Body is synonymous with mouth feel and viscosity (Clifford and Wilson, 1985) and/or linked with density viscosity of the brew (Petracco, 2000). However, there is no simple relationship between beverage viscosity measured instrumentally and body judged subjectively (Clifford, 1985). Flavor is the coffee's principal character, the mid-range notes, in between the first

impression given by the coffee's first aroma and acidity to its final after taste. It can be indicated by inhaling the vapor arising from the cup or nasal perception of the volatile substances evolving in the mouth (Petracco, 2000). In this regard, Agwanda (1999) compared four quality traits (acidity, body, flavor and over all standards) for their suitability as a selection criterion for the genetic improvement of over all liquor quality. This trait showed high genetic correlation with preference, was easy to determine organoleptically and had relative high sensitivity discriminating different coffee genotype (Agwanda, 1999). There is also high heritability for the over all standard of cup quality and possibility of good selection progress for this character with the assistance of experienced coffee tasters (Van der Vossen, 1985). In addition, based on correlation, repeatability and sensitivity analysis, flavor rating was recommended as the selection criterion for genetic improvement of cup quality in Arabica coffee (Yigzaw, 2006).

The ISO 6668 specifies the standard for sampling, roasting and grinding conditions and the preparation of the brew. There is a recently created new working group to elaborate a vocabulary for the sensory evaluation of coffee products (ISO, 2003a), accounting existing and published glossaries (Lingle, 1986; ITC, 2002; ICO, 2004; Pridolliet, 2004).

2.5.3 Geographic and botanic origin

It is obviously very important to know the geographic and botanical origin of coffee for the purpose of fair international trade [Prodolliet, 2004). On the other hand, the origins can be used either alone or in blends import to the finished product, its unique sensory characteristics. Furthermore, premium price is paid for certain origins, which also often stated on the label of

coffee product. Therefore, the purpose to checking the geographic and/or botanic origin of coffee is to support claims and to prevent any deliberate or accidental substitution of a product of reputed origin by a cheaper coffee originating from another country of region.

2.5.4 Coffee roasting

Green coffee must be roasted in order to give the final beverage- its unique sensory characteristics. Coffee can be roasted to various degrees, from very light to very dark. The degree of roast has direct impact on the sensory profile of the coffee cup, which is a matter of consumer preference. It has also a great influence on the particle size distribution after grinding and, consequently on the extractability of coffee. Therefore, the purpose of monitoring this parameter is to control the roasting process and to guarantee the consistent sensory quality of the finished produce (ISO, 2001; ITC, 2002; Prodolliet, 2004).

At the start of coffee roasting process, loosely bound water driven off and some shrinkage occurs, particularly with Arabica. As evaporative cooling declines, so the bean temperature rises and an exothermic pyrolysis begins in the temperature ranges of 140–160 ^{0}C, and leads to the formation of the well known color, aroma and taste of roasted coffee product. The pyrolysis peaks between 190 and 210 ^{0}C with enthalpies of 230-375 Jg^{-1}, and change begins at about 230^{o}C if it is not arrested. The acceptable dry matter loss ranges from some 35 for a very pale roast to some 14 % for a very dark roast. The corresponding figures for total roasting loss (dry matter and water) are some 10 percent and 25 percent, respectively (Clifford, 1985). Uneven roast results in poor quality liquor, and dark roast enhances the body, while light roast emphasizes acidity (ITC, 2002).

A large quantity of carbon dioxide is produced; its expansion generates internal pressure in the range from 5.5 to 8.0 atmospheres and accounts for the swelling of the bean by some 170–230 percent during commercial roast, its partial escape for the loss of dry matter (Clifford, 1985). Arabica coffee can attain 16 percent volume increase at 188^{o}C, 30 min. and 4.87 percent pyrolysis loss and 2.9 percent pyrolysis loss (Clifford, 1985). This implies that the difference is due to vapor ($C0_2$) production, vapor ($C0_2$) retention; vapor ($C0_2$) expansion; resistance of the cell wall complex to tensile stress (Clifford, 1985).

2.5.5 Cleanliness of the coffee extract

Insoluble substances can be formed during extraction (Clark, 1985). These substances eventually carried over to the soluble coffee powder leading to an “unclear” coffee cup after reconstitution with hot water. Therefore, the purpose of measuring the cleanliness of the extract is to control the extraction and evaporation steps and to ensure a clean coffee cup (Prodolliet, 2004).

2.5.6 Good laboratory practice

The accuracy and reliability of analytical results is only achieved by the implementation of good laboratory practice (GLP). GLP principles are presented in many official documents (CITAC/ EURACHEM, 2002) and the key points are:

- The analytical methods used must be properly validated (CITAC/ EURACHEM, 2002) The validation process aims at establishing the performance characteristics of a method (e.g. working range, trueness, precision) and proving its fitness for purpose
- The performance of the equipment and analytical methods must be monitored by applying an internal control plan (ICP). The sample sets used for the calibrator and the validation must be independent with a sufficient number of sample
- The laboratory should participate in proficiency tests.

Ideally, Hazard Analysis and Critical Control Points (HACCP) can be implemented through out the supply chain. A HACCP plan has already been proposed from the coffee filed to the storage and transport of green coffee, mainly in the perspective of occurrence of OTA (CITAC/ EURACHAM, 2002). Therefore, keeping consumers trust is essential. It can be achieved by delivering day after day a product with consistent quality. However, quality is not a matter of chance. It can be made by people and is the result of deliberate actions. It is a joint effort by all the key players who involved in the coffee production to consumer chain. It is certainly worth implementing and running quality assurance programs, as quality is, at the end, a competitive advantage (ISO, 2000; Prodolliet, 2004; ITC, 2002).

3 Materials and methods

3.1 Description of the study area

The experiment was carried out at the Awada Agricultural Research Sub-Center and its adaptive trial sites; namely Konga and Korke in 2008 cropping season. Awada is located 6°3'N Latitude and 38°E Longitude with an altitude of 1750 meters above sea level with the respective annual mean minimum and maximum rainfall of 858.1 mm and 1676.3 mm. The annual average minimum and maximum air temperatures are 11.0^{0}C and 28.4 ^{0}C, respectively. The major soil types of the research center are *Eutric Nitosol* and *Chromotic Cambisols* that are highly suitable for coffee production. Mesincho Pa is located 6^{0}58'N 38^{0}44'E with an altitude of 1785m with 1000mm minimum and 1300mm maximum annual rain fall, and Gane Pa is located 6^{0}45'N 38^{0}32'E with an an altitude of 1845m with 1000mm minimum and 1300mm maximum annual rainfall in Yirgalem town of the Southern Ethiopia.(IAR, 1996). The Korke adaptive trial site is located 6°37'30"N Latitude and 38°21'15"E Longitude in Sidama Zone, Aleta Wondo woreda. It is characterized as mid-altitude area with an altitude of 1780 m a.s.l. Konga is located 6° 38'N Latitude 21' 15"E Longitude in Gedeo zone, Yirgacheffee woreda. It is located at high altitude with an altitude of 1950 m above sea level (IAR, 1996).

3.2 Experimental material

Arabica coffee genotypes (12 from southern and 2 from southwestern) that have been established at Awada Research Center, Korke and Konga trial sites were used for the study. These were planted in July 2004 using a spacing of 1.5 m between plants and 2.0 m between rows. All field management practices were uniformly applied to all plots as per the

recommendation of the Center (IAR, 1996). In addition, three coffee landraces were included from three PAs of the Dale district to represent the Sidama coffee types (Table 1). Hence, a total of 17 coffee genotypes and 405 coffee samples were used for the study (135 for washed, 135 for semi-washed, and 135 for sun dried).

Table 1. List of coffee genotypes and their place of origin in the study areas

Genotype	Zone	Wereda	Kebele
971	Gedeo	Gelana Abaya	, Hafursa Bergesa (Negele)
974	Gedeo	Gelana Abaya	Hafursa Bergesa (Negele)
979	Gedeo	Gelana Abaya	Hafursa Waro (Goro-Gore)
9718	Gedeo	Gelana Abaya	Shara Bukisa (Gobena Wome)
9722	Gedeo	Gelana Abaya	Shara (Homa)
9744	Gedeo	Kochere	Sigiga (Gilinde)
1377	Gedeo	Wonago	Quoti (Wonago Research station)
85237	Gedeo	Yirga Cheffe	Konga
85238	Gedeo	Yirga Cheffe	Chelba
85257	Gedeo	Yirga Cheffe	Deko (
85259	Gedeo	Yirga Cheffe	Deko
85294	Sidama	Aleta Wondo	, Dongora Qabado
744			CBD resistant from southwest Ethiopian
75227			CBD resistant from Southwest Ethiopian
L1	Sidama	Dale	Awada PA *
L2	Sidama	Dale	Mesincho PA*
L3	Sidama	Dale	Gane PA*

Source: Ethiopian Institute of Agricultural Research and * are own collection

3.3 Experimental design

The treatments were arranged using factorial experiment in complete randomized design with three replication. The treatments consists of 17 genotypes including the three local land racess (L1, L2, and L3) with three processing method at Awada and 14 genotypes with three processing method at Korke and Konga to assess the variability among locations, coffee

accessions, and processing methods. The treatments were arranged as main and interaction effects as described by Gomez and Gomez (1984).

3.4 Experimental materials and procedures

Experimental material used at the field during processing includes harvesting baskets, red coffee cherries, fermentation pots, drying tables, mesh wire, Hessian, plastic films, hand held pulper, and during laboratory analysis includes dunken joy moisture tester, batch roaster, grinder, cups, cupping spoon, distilled water, spittoons, working sheet. The treatments were evaluated for physical and sensorial factors.

3.4.1 Sun dried coffee

51 samples from Awada site including the land races and 84 samples from Korke and Konga (42 from each) prepared as sun dried/natural. During preparation selectively picked red cherries 5kg per sample collected from all sites prepared at Awada research sub station sub center. The red cherries labeled and properly dried on raised compartmented drying table (0.8m above the ground) and regularly turned to maintain uniform drying. Finally, after three weekdr dying, the dried coffee pods (at 11.5% moisture content) were separately labeled and packed.

3.4.2 Hulling (de husking)

Using hulling machine and catador, dried pods were hulled, cleaned and polished and finally 1kg clan green bean obtained per sample and used as dry processed Arabica (DPA) (ISO 10470, 2004).

3.4.3 Washed coffee

51 samples from Awada site including the land races and 84 samples from Korke and Konga (42 from each) prepared as washed. During preparation, selectively picked red cherries 5kg per sample collected from all sites were prepared at Awada research sub center using hand held pulping machine. Red cherries sorted by dipping with water to separate floaters and 5kg red cherries used per experimental unit. The cherries separately pulped and immediately after pulping the parchment sorted from the pulp and dipped in to water to separate the floaters. The moist parchment fermented using fermentation pot. After fermentation when the slippery mucilage removed washed and socked with clean water and dried. The whole processing steps done according to the standard recommended for the specified altitude range (Behailu et al., 2008). The dried parchment (11.5 % moisture) separately labeled and packed. Finally, the parchment removed and 1kg clan green bean obtained per sample and used as an input for this result as wet processed Arabica coffee (ISO 10470, 2004).

3.4.4 Semi washed

Fifty-one samples from Awada site including the land races and 84 samples from Korke and Konga (42 from each) prepared as semi washed. During preparation, selectively picked red

cherries 5kg per sample pulped at Awada research sub center using hand haled pulping machine and immediately after pulping the moist parchment with its mucilage taken to the compartmented drying table. After two week drying, the dried parchment separately labeled and packed. Finally, the parchment hulled and cleaned using huller and Catador. Finally, the parchment removed and 1kg clan green bean obtained per sample and used as an input as clean semi washed Arabica for this result (ES 589, 2001).

3.4.5 Labeling and packing

Each coffee sample was prepared from each sites as indicated during processing and separately labeled (having the name of accession number, processing method, site, and other details). The samples were packed and brought to Addis Ababa Coffee Quality Inspection and Grading Center for quality analysis.

3.5 Data collection

During data collection all quality attribute of green bean (screen size and moisture) and quality factors (shape and make, color, odor, cup cleanliness, acidity, body, flavor, and characteristics) were considered as per the standard recommendation (ISO, 1991; ISO 5492: 1992; ISO 9116, 1992; WD 4257: 2000; ES 589: 2001; QSAE WD4467: 2000 identical with ISO10470:1993; CQIGC, 2008).

3.5.1 Quality evaluation

Code: The samples separately coded in the coding room according to the standard procedure employed in the Coffee quality Inspection and Grading Center to avoid individual biasness of the panel, including the researcher.

Moisture content: The moisture content of each sample bean was measured with a standard moisture tester (dickey joy) certified by Quality and Standard Authority of Ethiopia.

3.5.2 Amount of green bean

From each samples, 300 g of green bean used for physical /raw analysis and 100 g of green bean used for roasting. According to coffee, brew preparation for sensory evaluation was accomplished as described by WD of QSAE 4257: 2000, which is identical with ISO 6668: 1991).

3.5.3 Raw quality analysis

During raw/physical quality analysis, 300g of green bean was used for each sample and their shape and make, color, odor, were measured according to the Ethiopian standard (ES 589: 2001) and these data were evaluated based on green coffee reference chart which is a published Working Draft 4467: 2000 by QSAE identical with ISO 10470: 2004.

Shape and make: Evaluated as very good, good, fairly good, average, and small and weighted accordingly.

Color: Evaluated as blue, bluish, greenish, coated, faded, and weighted accordingly.

Odor: Olfaction evaluated as clean, fairly clean, light, moderate, and strong.

Screen analysis: Bean size distribution was carried out by means of rounded perforated plate called screen. The size of the screen holes was specified in 1/64 in. the data measured based on coffee bean retained between screen 12 and 19.

Bean weight: Weight of 100 beans for each sample was measured using sensitive weight scale. The weight measured recorded in gram.

3.5.4 Roast analysis

A batch roaster equipped with a cooling system in which air was forced through a perforated plate, capable of roasting up to 500 g of green coffee bean used for roasting. 100 g of sample bean was used for each sample and placed in the batch roaster and carefully roasted the bean until they attain medium brown roast color (7–8 minute) with roasting temperature of 170 - 200 ^{0}C.

Dry matter: 100 grams of green bean from each samples of coffee before and after roast measured and the data recorded using sensitive weight scale. The weight difference recorded in gram.

Volume: 100 grams of green bean from each samples of coffee before and after roast measured and the data recorded using gradated cylinder. The volume difference after roast recorded in g/cm$^{3.}$

3.5.5 Brew preparation

The water used as a reagent contains 0.3 m mol to 1.2 m mol calcium carbonate ($CaCO_3$), which is free from chlorine or other foreign flavor affecting the test. According to the volume

of water used for the preparation of the beverage, using the balance 12 g of roasted and ground coffee per 250 ml of water used. Using the preheating graduating cylinder boiled water (93^0C) pored into cup containing the test portion and allowed the infusion to steep for approximately 4 minute to permit the ground settle. After 4 minute, breaking the cup made for aroma then skimmed off the surface of the beverage to remove foams (remaining ground) and allow the beverage to cool not greater than 55^0C for tasting (ISO, 6668:1991).

3.5.6 Cup quality analysis

For each treatment sample using the round soupspoon raise 6 to 8 cc of liquid to just in front of the mouth and forcefully slurp the liquid. By briskly aspiring, the coffee in this way spread evenly over the entire surface of the tongue. A team of trained, experienced and internationally certified Q grader cuppers made this. In this case, five expertises including the researcher participated in a panel for cupping to evaluate the aroma and taste characteristics of each sample of the brew involving olfaction, gestation, and mouth feel sensation. Average result of cuppers used for the analysis.

Cup acidity: During cup acidity analysis, evaluated as, pointed (15%), and moderately pointed (12 %), medium (9 %), light (6 %) or lacking (3 %) and the result accordingly recorded.

Body: Cup body evaluated as, full (15 %), moderately full (12 %), medium (9 %), light (6 %), and thin (3 %). The result recorded accordingly.

Flavor: The flavor, the over all test of the brew evaluated and recorded as good (15 %), fairly good (12 %), average (9 %), fair (6 %) and commonish (3 %).

Character: Character is the test of the coffee, which is unique to that area coffee genotypic character. Based on preference rating for the specific origin weighted as outstanding (10/10), excellent (9/10), fine (8/10), very good (7/10), good (6/10), Average (5/10), fair (4/10), acceptable (3/10), poor (2/10) and very poor (<2). The result recorded accordingly.

Yield: Coffee yield was recorded per tree and converted into clean coffee in quintal per hectare.

3.5.7 Soil analysis

Composite soil samples were randomly collected from all experimental areas from a depth of 0 – 40 cm using core sampler auger. The collected samples analyzed for pH, EC, Total N, available phosphorous, organic carbon, organic matter, CEC, Ca, Mg, Na, and K. from six sample sites. The analyses were accomplished in the soil laboratory of the Agricultural and rural development office of Southern Nations, Nationalities, and Peoples' Regional State. The distribution of soil particles (sand, silt, clay) were determined to know the textural class of the soil. The chemical properties include total N, available phosphorous, Ca, Mg, K, CEC, EC, OM, OC, pH.

3.5.8 Statistical analysis

Two-way analysis of variance (ANOVA) was computed for each character in order to identify the variability among the coffee genotypes and processing methods at three location using the procedures described by Gomez and Gomez (1984). For this, SAS computer software version 9.0 was employed for the ANOVA and for the correlations between the variables. Treatment mean separation was made whenever significant differences were noticed at 5 % probability level.

4 Result and discussion

4.1 Soil properties

The results show the highest soil pH of 5.9 was found at Awada Research Center while the lowest pH of 4.9 was obtained from Korke soil. The soil at Konga had the highest total nitrogen (0.53%) content, while that of Awada research center had (0.39). The highest organic matter (6.45 %) was determined for soil sample collected from Mesincho farmers. This was in contrast to the lowest organic matter content (4.42%) recorded at Awada and Konga sites. Soil sample collected from coffee plot at Awada PA had the highest available phosphorous (7.20 ppm), while the lowest (0.20 ppm) was being recorded from the coffee plot at Gane PA. The soil physico- chemical characteristics were presented in Table 2.

Table 2. Soil physico-chemical characteristics of the experimental areas

Parameter	Unit	Awada Research	Korke	Gane PA	Awada PA	Mesncho PA	Konga
pH	water (1:2.5)	5.9	4.9	6.2	6.6	6.3	5.7
Ec	µS	1.3	0.4	1.3	2.6	2.2	3.3
N	%	0.39	0.41	0.46	0.45	0.41	0.53
P	ppm	2.6	0.8	0.2	7.2	2.0	4.0
OC	%	2.54	3.22	3.22	3.02	3.71	2.54
OM	%	4.42	5.6	5.6	5.27	6.45	4.42
CEC	Meq/100g	20	28	34	35	32	30
Ca	Meq/100g	14	8	18	18	18	29
Mg	Meq/100g	18	9	11	12	12	5
Na	Meq/100g	0.02	0.02	0.02	0.02	0.02	0.02
K	Meq/100g	0.22	0.17	0.27	0.31	0.31	0.12
Sand	%	38.2	36.2	34.2	34.2	36.2	34.2
Clay	%	18.16	14.16	22.16	22.16	14.16	22.16
Silt	%	43.64	49.64	43.64	43.64	49.64	43.64
Texture class		Loam	Loam	Loam	Loam	Loam	Loam

EC = Electrical conductivity, TN = Total nitrogen, P = available phosphorous, OC = Organic carbon, OM = Organic matter, CEC = Cat ion exchange capacity, Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium

4. 2 Effect of processing on coffee quality

Except for bean size, the other quality parameters were significantly different at ($P \leq 0.05$) among coffee processing method practiced at the two study sites (Table 3). At Awada, the top medium pointed to pointed acidity was recorded under wet processing method with a mean value of 12.51. The medium acidity was recorded under sun dried processing method with a mean value of 10.46.However,coffee subjected to sun dried had the highest medium to full body (12.42) while coffee sample subjected to washing treatment showed the lowest medium body of 10.27(Table 3). Significant difference at ($P \leq 0.05$) were detected in total quality due to processing treatment (Appendix 3).The highest overall total quality was noticed under wet processing as opposed to the least value for the sun dried coffee (Tables 3). Similarly, wet processed coffee from Konga had the highest ($P \leq 0.05$) acidity while on the other hand sun

dried coffee from Konga showed the lowest total acidity of 9.59. The highest medium full body was found when the coffee was sun-dried. In a contrast, the least body was determined for the washed coffee types (Table 3). The findings of the present work supported by Clark (1985) in that the use of wet processed arabica can result in best aromatic with fine and pointed acidity. And the use of under water fermentation as opposed to 'dry' accentuates the formation of acids. Jakelers and Jackels (2005) indicated that fermentation in wet processed coffee, it break the cellulose of the mucilage layer converting the parchment husk enclosing the bean and increase the acidity of the coffee. According to Clifford (1985), the wet processed arabica is aromatic with fine acidity and some astringency, while dry processed Arabica is less aromatic but with grater body.

Table 3. Effect of coffee processing method on coffee quality

Variable	Washed	Semi washed	Sun dried	ANOVA
Sidama (Awada)				
Shape and make	11.99[a]	9.91[b]	9.22[c]	***
Color	11.12[a]	8.74[b]	8.82[b]	**
Acidity	12.51[a]	11.25[b]	10.46[c]	***
Body	10.27[b]	10.68[b]	12.42[a]	***
Character	5.06[b]	4.67[b]	5.71[a]	***
Roast volume	32.26[b]	35.81[a]	39.37[a]	**
Roast weight	25.52[a]	21.68[b]	17.84[c]	***
Screen	93.22	93.60	94.00	NS
Bean weight	16.99	16.78	16.56	NS
Total quality	82.49[a]	76.97[b]	76.93[b]	***
Yiracheffee (Konga)				
Shape	10.47[a]	9.46[b]	9.04[c]	***
Color	10.10[a]	9.86[a]	8.04[b]	***
Acidity	11.07[a]	10.78[a]	9.59[b]	***
Body	10.52[b]	10.07[b]	11.98[a]	***
Character	6.05[a]	3.86[b]	6.43[a]	***
Roast volume	42.93[a]	38.32[b]	36.07[b]	**
Roast weight	17.81[b]	20.79[a]	19.94[a]	**
Screen	90.14[c]	93.30[b]	94.82[a]	*
Bean weight	14.54	14.72	14.44	NS
Total quality	79.41[a]	74.69[b]	73.93[c]	***

Figures followed by the same letter(s) within a column are not significantly different from each other at 0.05. NS, *, **, ***, Not significant ($P>0.05$), significant at ($P<0.05$), ($P<0.01$), or ($P<0.001$) respectively.

4.3 Shape and make

There was very significant ($P\leq0.001$) variation in the shape and make of coffee accessions planted at Awada (Appendix 1). The highest figure was recorded for 9718 with an average value of 13.75, which is a very good shape and make with more uniform appearance (Table 4). The lowest (6.5) was recorded from accession 85238, indicating its smallest bean size. The relationship between bean appearance and other coffee quality parameters was positive and

highly significant (P≤0.05) correlated with the color (r = 0.76), acidity (r = 0.55), body (r = 0.76), roast weight (r = 0.39), screen (r = 0.51), bean weight (r = 0.49) and total quality (r = 0.76) of Sidama coffee (Appendix 4).

Coffee accessions depicted very high significant variation for the shape and make evaluated at Korke (Appendix 1b) with the highest (12) and lowest (7.33) average values obtained for 979 and 75227, respectively (Table 4). From the correlation results, it is also possible to predict the other quality aspects of coffee genotypes. Similar to that of Awada, shape and make of coffee beans significantly (P≤0.05) and positively correlated with bean color (r = 0.52), body (r = 0.35), roast volume (r = 0.38), bean weight (r = 0.41), acidity (r = 0.28) and bean size (r = 0.18) in the Sidama types (Appendix 5).

The Yirgacheffee coffee types at Konga revealed highly significant (P≤0.05). Variation among accessions (Appendix 3). Hence, the highest (11) result with an average to good bean size was recorded from 85257. This was in contrast to 85294 with the smallest bean size. Here, the shape and make of coffee beans was significantly (P≤0.05) correlated with screen size (r = 0.22), color (r = 0.84), acidity (r = 0.34), roast volume (r = 0.45), bean weight (r = 0.53) and total quality (r = 0.59) in the Yirgacheffee (Appendix 6).

Under the wet processing method applied at Awada Research Center where the local Sidama type, 9718, 9744 and 9722 were known to have very good shape and make with a uniform appearance. On the other hand, such accessions as 85238, 744 and 85238 were characterized by smaller beans (Table 4). This was also the case at Korke where the wet processed 9744 and the sun dried 979 were noticed to have the highest values and thus have good and uniform

shape and make (Table 4). Accordingly, accessions 85277, 9718 and 744 had very good shape and make both under wet and sun dry processing (Table 4). This corroborates with Bertrand et.al. (2004) and Sivetz and Dosrosier (2005) who pointed out similar variability due to botanical variety and environmental growth circumstances.

Table 4. The effect of processing method on the shape and make of coffee bean at different locations

	Sidama (Awada)				**Sidama (Korke)**				**Yirgacheffee (Konga)**			
Coffee genotype	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**
85238	6.00^{g}	6.00^{g}	7.50^{defg}	6.50^{j}	9.25^{ced}	6.00^{ef}	9.25^{cde}	8.17^{fgh}	9.00^{def}	7.20^{e}	6.50^{cde}	7.98^{de}
9718	15.00^{a}	13.50^{a}	12.75^{a}	13.75^{a}	9.00^{ed}	7.00^{de}	9.00^{de}	8.33^{fg}	12.00^{ab}	9.00^{dc}	8.75^{abc}	9.83^{bc}
85237	12.75^{bcd}	6.75^{ih}	7.50^{defg}	9.00^{h}	9.25^{cde}	8.00^{cd}	9.25^{cde}	8.83^{efg}	10.50^{bcd}	9.60^{bc}	8.50^{abcd}	9.62^{c}
974	14.75^{a}	11.25^{cd}	6.50^{fg}	10.83^{ef}	9.00^{de}	6.00^{ef}	9.00^{de}	8.00^{gh}	10.50^{bcd}	10.00^{abc}	9.00^{abc}	9.83^{bc}
1377	12.00^{cde}	8.25^{ghf}	7.75^{def}	9.33^{gh}	8.50^{e}	10.00^{b}	8.50^{e}	9.00^{def}	10.50^{bcd}	9.00^{dc}	8.75^{abc}	9.33^{c}
9744	15.00^{a}	12.00^{cab}	14.75^{a}	13.25^{ab}	12.00^{a}	9.00^{bc}	12.00^{a}	11.00^{ab}	11.25^{abc}	11.40^{a}	9.25^{abc}	10.97^{ab}
979	13.50^{abc}	11.75^{bc}	12.00^{ab}	12.41^{bc}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	11.25^{abc}	11.40^{a}	10.75^{a}	10.97^{ab}
9722	15.00^{a}	12.91^{ab}	11.25^{ab}	13.05^{abc}	10.00^{bcde}	9.00^{bc}	10.00^{abcd}	9.67^{cde}	11.25^{abc}	10.80^{ab}	7.66^{abcd}	9.21^{cd}
85294	10.50^{ef}	7.50^{ghi}	8.25^{de}	8.75^{h}	10.50^{abcd}	10.00^{b}	10.50^{abcd}	10.33^{bc}	7.88^{a}	6.60^{e}	4.00^{e}	6.33^{f}
85259	14.25^{ab}	8.25^{gfh}	8.25^{de}	10.25^{f}	9.00^{de}	6.00^{ef}	9.00^{de}	8.00^{gh}	8.25^{ef}	6.60^{e}	6.83^{cde}	7.84^{e}
85257	9.75^{f}	9.75^{edf}	6.75^{efg}	8.75^{h}	9.25^{ced}	10.00^{b}	9.25^{ced}	9.50^{cde}	12.75^{a}	11.40^{a}	10.25^{ab}	11.38^{a}
971	14.25^{ab}	11.25^{cd}	11.25^{ab}	12.25^{cd}	10.80^{abc}	8.00^{cd}	10.88^{abc}	9.92^{cd}	9.75^{edc}	10.20^{abc}	9.50^{abc}	9.73^{bc}
744	7.50^{g}	9.25^{ef}	6.00^{g}	7.58^{i}	11.60^{ab}	10.00^{b}	11.63^{ab}	11.09^{ab}	12.00^{ab}	11.40^{a}	7.17^{bcde}	9.58^{c}
75227	9.75^{f}	9.00^{efg}	6.75^{efg}	8.50^{h}	8.50^{e}	5.00^{f}	8.50^{e}	7.33^{h}	9.75^{ced}	7.80^{de}	5.33^{de}	7.93d^{e}
L1	11.25^{def}	10.00^{de}	10.50^{bc}	10.58^{ef}								
L2	11.25^{def}	11.00^{cd}	12.00^{ab}	11.42^{de}								
L3	11.25^{def}	10.00^{de}	9.00^{cd}	10.08^{gf}								
LSD(0.05)	1.63	1.66	1.66	0.91	1.67	1.67	1.67	0.98	1.67	1.67	24.77	1.31
CV (%)	8.21	10.09	10.68	9.38	10.08	12.06	10.08	11.19	9.55	10.57	24.77	15.06

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.4 Color

The results show highly significant (P≤0.001) variations among accessions and processing methods at the three study sites (Appendix 1). Thus, for the Sidama coffee the highest result with the greenish to grayish color and the least coated to greenish were found for coffee genotypes 979 and 85238, respectively. At Korke, the highest color value was recorded for accession 9718, least was being for 75227. Among the Yirgacheffe accessions, the highest result was obtained for 85257, with greenish to grayish color. In a contrast, the least value was measured for accession 85294 (Table 5).

The simple correlation results depicted that bean color was significantly (P≤0.05) and positively correlated with body (r = 0.22**), screen (r = 0.24**), acidity (r = 0.57***), character (r = 0.30***), roast weight decrease (r = 0.45***), bean weight (r = 0.37**) and total quality (r = 0.67***) at Awada for the Sidama type (Appendix 4). At Korke, the color of coffee beans also significantly (P≤0.05) to body (r = 0.38***), roast volume increment (r = 0.31***), total quality (r = 0.53***), character (r = 0.25**) (Appendix 5). Similarly, this relationship was significantly (P≤0.05) positive with body (r = 0.22*), roast weight increment (r = 0.24**), screen (r = 0.27**), acidity (r = 0.54***), roast volume increment (r = 0.8***), bean weight (r = 0.57***) and total quality (r = 0.62***) for the Yirgacheffe type studied at Konga (Appendix 6).

Regarding the interaction effect between coffee genotype and processing methods, significance variations (P<0.001) were detected for bean color at all locations (Appendix 3). Accordingly, the Sidama genotypes 979 and 9718 showed a bluish color while 971 had

grayish colors. Accessions 85238 and 744 exhibited the least color of coated and greenish due to the wet processing practice. However, the sun-dried genotypes L3, 9718, L1 and 971 showed greenish color, while 85238 and 1377 scored the lowest result with coated to greenish color (Table 5).

At Korke, the washed 9718 coffee type had a greenish to grayish color, whereas, accessions 979 and 85259 had green color. Accession 75227 showed a coated to greenish color with the least with a value of 8.16 when wet processed (Table 5). Under sun dried processing, accession 9718 depicted the highest mean value of 10.25, but the least was from accessions 1377, 9722, 85257, and 75227 (Table 5). At Konga, under washed coffees for the Yirgacheffe types, accession, 85257 showed a grayish color with a mean value of 12.38, which was followed by 9718 and 85237 with grayish to greenish color.. Nonetheless, the least color value was recorded for 85259 and 971, which represent greenish to coated color (Table 5).

The present finding support Anon (2001), who pointed out that the best color of the bean, green blue can be obtained by removing the mucilage under fermentation after removing the pulp in wet processing. According to Sutherland (1990), the beans with the poorest appearance can be observed when the red cherry harvested and dried with their skin under sun dried processing. Davids (2001) also confirmed that the green bean color was best where the mucilage had removed by fermentation under water in wet processing and the poorest color was obtained when the bean dried inside the fruit.

Table 5. The effect of processing method on the color of coffee beans at the three locations

	Sidama (Awada)				**Sidama (Korke)**				**Yirgacheffee (Konga)**			
Coffee genotype	**Wet**	**Semi-washed**	**Sun dried**	**Mean**	**Wet**	**Semi-washed**	**Sun dried**	**Mean**	**Wet**	**Semi-washed**	**Sun dried**	**Mean**
85238	6.00^{e}	6.75^{d}	7.50^{b}	6.78^{f}	9.66^{ab}	8.00^{ab}	9.25^{ab}	9.11^{abc}	9.00^{cd}	9.20^{dc}	7.33^{b}	8.51^{fg}
9718	14.25^{a}	9.00^{abc}	9.75^{a}	11.00^{a}	10.41^{a}	8.00^{ab}	10.25^{a}	9.61^{a}	11.25^{ab}	9.60^{bdc}	7.75^{ab}	9.53^{cde}
85237	12.00^{bc}	8.25^{bcd}	8.25^{ab}	9.50^{bcde}	8.91^{bc}	8.00^{ab}	8.75^{ab}	8.61^{cde}	11.25^{ab}	10.20^{bc}	8.25^{ab}	9.90^{bcd}
974	10.50^{c}	9.00^{abc}	9.00^{ab}	9.50^{bcde}	9.16^{b}	7.00^{b}	9.00^{ab}	8.44^{cde}	9.75^{bcd}	9.10^{dc}	8.5^{ab}	9.12^{cdefg}
1377	11.25^{bc}	7.50^{cd}	7.50^{b}	8.75^{e}	8.16^{c}	8.50^{ab}	8.00^{b}	8.28^{cde}	10.50^{bc}	9.60^{bdc}	8.17^{ab}	9.42^{cdef}
9744	10.50^{c}	9.00^{abc}	9.00^{ab}	9.50^{bcde}	8.91^{bc}	9.00^{a}	8.75^{ab}	8.94^{abcd}	10.50^{bc}	10.20^{bc}	9.33^{ab}	10.01^{abc}
979	14.25^{a}	9.75^{ab}	9.00^{ab}	11.00^{a}	9.66^{ab}	9.00^{a}	9.50^{ab}	9.44^{ab}	10.50^{bc}	12.00^{a}	9.50^{a}	10.67^{ab}
9722	12.25^{b}	9.00^{abc}	9.00^{ab}	10.08^{abc}	8.16^{c}	8.00^{ab}	8.00^{b}	8.11^{de}	10.50^{bc}	9.90^{bdc}	8.25^{ab}	9.55^{cde}
85294	10.75^{cd}	8.25^{cdb}	8.25^{ab}	9.08^{de}	9.66^{ab}	8.00^{ab}	9.50^{ab}	9.11^{abc}	9.38^{cd}	8.40^{d}	7.41^{b}	8.40^{g}
85259	11.50^{cb}	7.50^{cd}	9.00^{ab}	9.33^{cde}	9.66^{ab}	8.00^{ab}	9.50^{ab}	9.11^{abc}	8.25^{d}	8.40^{d}	9.08^{ab}	8.58^{efg}
85257	10.75^{cb}	8.00^{abc}	8.25^{ab}	9.33^{cde}	8.16^{c}	9.00^{a}	8.00^{b}	8.44^{cde}	12.38^{a}	11.10^{ab}	9.50^{a}	10.99^{a}
971	12.25^{b}	9.00^{abc}	9.75^{a}	10.33^{ab}	9.16^{b}	8.00^{ab}	9.00^{ab}	8.78^{abcd}	8.25^{d}	10.50^{abc}	8.75^{ab}	9.17^{cdefg}
744	8.25^{d}	9.75^{ab}	8.25^{ab}	8.75^{e}	8.91^{bc}	9.00^{a}	8.75^{ab}	8.94^{abcd}	10.13^{bc}	10.20^{bc}	7.33^{b}	9.22^{cdefg}
75227	10.75^{cb}	9.75^{ab}	$8,25^{ab}$	9.58^{bcde}	8.16^{c}	7.00^{b}	8.00^{b}	7.78^{e}	9.75b^{cd}	9.60^{bdc}	7.50^{ab}	8.95^{defg}
L1	11.25^{cb}	8.00^{cd}	9.75^{a}	9.66^{bcde}								
L2	11.25^{cb}	10.00^{a}	9.75^{a}	10.33^{ab}								
L3	11.25^{cb}	9.00^{abc}	9.75^{a}	10.00^{bcd}								
LSD(0.05)	1.63	1.7	1.66	0.98	0.96	1.67	1.59	0.85	1.67	1.67	2.08	1.01
CV (%)	8.86	11.71	11.16	10.26	6.37	12.23	8.23	10.39	9.9	10.14	14.81	11.41

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.5 Acidity

Acidity is a primary coffee test sensation, and a high acid coffee has a pointed sharp pleasing flavor. Sidama coffee genotypes showed significant variations (P≤0.001) with acidity at Awada (Appendix 1), Korke (Appendix 2) and Konga (Appendix 3). Consequently, at Awada the highest moderately pointed to pointed acidity was recorded for the local landrace (L-3), while the least medium acidity recorded for the accession 85294. Similarly, accession 9722 and 85294 depicted the highest medium pointed to pointed acidity and the least medium acidity respectively at Korke. At Konga, 9744 had the highest medium pointed acidity, the least medium acidity was being recorded for coffee accession 971 (Table 6).

The results also demonstrate its significant (P≤0.05) and positive correlations with body (r = 0.52***), character (r = 0.59***), roast volume increment (r = 0.29), roast weight loss (r = 0.38), screen (r = 0.35***), bean weight (r = 0.44***) and total quality (r = 0.75***) in the Sidama coffee type (Appendix 4). This was also observed at Korke where acidity also significantly (P≤0.05) and positively correlated with shape and make (r = 0.28**), body (r =.19*), bean weight (r = 0.20*), character (r = 0.42***), roast volume increment (r = 0.33*), roast weight loss (r = 0.39***), screen (r = 0.30***) and total quality (r = 0.49***) (Appendix 5). The acidity of Yirgacheffe coffees was also significantly (P≤0.05) and positively correlated with color (r = 0.22), character (r = 0.6***), body (r = 0.53***), roast volume increment (r = 0.46***) and total quality (r = 0.53***) (Appendix 6).

With regard to the influence of processing treatments, on the coffee acidity at Awada, accession 9722 had the highest pointed acidity and followed by L3, while the least acidity was

recorded from the wet processed 85294 (Table 7). Likewise, the sun dried local coffee landraces (L1, L2, L3) had medium pointed acidity as opposed to the least acidity determined for accession 85259. The semi-wet processing resulted in medium pointed acidity of landrace L1. This was however least for the semi-washed 85259 (Table 6).

At Korke, the accession 9722 had the highest pointed acidity with a mean value of 14.5 as compared to the medium acidity recorded for the 85294. Under sun drying, accession 9722 and 9718 scored medium pointed acidity while accession 75227 had light acidity. The semi-washed Sidama coffees such as genotype 9722, 9744, 971 85257 and 9718 were found to have medium pointed acidity (Table 6).

Similarly, at Konga the wet processing technique showed significant ($P \leq 0.05$) variability where genotype 9744 had medium pointed to pointed acidity. This was followed by genotype 9722 and 85294 with a medium pointed acidity and with the respective value of 13.25 and 12.75.However, accession 9744 had light to medium acidity. In the case of natural/sun drying, accession 9744 and 9722 scored medium pointed to pointed acidity with a mean value of 13.5 and 13.25, respectively, while genotype 85257 had light to medium acidity. The semi-washed accession 75227 and 9744 had medium pointed acidity. As shown in Table 6, accession 85238 and 85294 showed medium acidity level which is in agreement with that of Yigzaw (2006) who found variations in acidity among coffee genotypes collected from the different parts of Ethiopia. According to Agawanda (1999), acidity and body are reliable and suitable quality attribute that can be used as selection criteria for the genetic improvement of the over all liquor quality. Clark et al. (1988) reported that the use of under water fermentation instead of

'dry' accentuates the formation of acids. Jackelers and Jackels (2005) confirmed that fermentation in wet processed coffee can break the cellulose of the mucilage layer converting the parchment husk enclosing the bean and increases the acidity of the coffee.

Table 6. Coffee acidity as affected by the various processing methods at different locations

	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
Coffee genotype	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**
85238	12.00^{cd}	10.13^{cde}	10.50^{bc}	10.87^{def}	12.00^{bc}	10.00^{bc}	10.50^{ab}	10.83^{bcde}	9.00^{ef}	9.90^{c}	9.75^{abc}	9.55^{de}
9718	12.25^{d}	12.38^{abc}	$12.00.^{bc}$	11.87^{abcde}	11.25^{c}	13.00^{a}	12.00^{a}	12.03^{ab}	11.00^{bcde}	10.80^{abc}	10.5^{ab}	10.77^{bcd}
85237	11.25^{d}	13.13^{ab}	10.50^{bc}	11.62^{bcde}	11.25^{c}	9.00^{c}	9.00^{b}	9.75^{cde}	11.25^{abcde}	10.80^{abc}	9.00^{bc}	10.35^{cde}
974	12.00^{cd}	10.88^{bcde}	10.50^{bc}	11.13^{def}	12.00^{bc}	11.00^{abc}	6.00^{c}	9.67^{cde}	10.50^{cdef}	10.80^{abc}	9.00^{bc}	10.01^{cde}
1377	13.75^{abc}	9.75^{ef}	9.75^{cd}	10.83^{ef}	13.75^{abc}	10.50^{abc}	10.00^{ab}	11.58^{bc}	10.25^{edf}	10.50^{abc}	7.50^{c}	9.42^{de}
9744	14.50^{ab}	12.75^{ab}	11.25^{abc}	12.83^{abc}	14.50^{ab}	13.00^{a}	9.00^{b}	12.17^{a}	13.50^{a}	12.60^{ab}	12.00^{a}	12.70^{a}
979	13.50^{abc}	11.25^{abcde}	10.50^{bc}	11.75^{abcde}	13.50^{abc}	10.50^{abc}	9.75^{ab}	11.25^{bc}	11.00^{bcde}	10.20^{bc}	9.00^{bc}	0.07^{cde}
9722	15.00^{a}	11.25^{abcde}	10.50^{bc}	12.25^{abcd}	15.00^{a}	12.00^{ab}	9.00^{b}	13.00^{a}	13.25^{ab}	10.20^{bc}	12.00^{a}	11.82^{ab}
85294	8.00^{e}	9.75^{def}	7.50^{de}	8.42^{h}	8.00^{d}	11.00^{abc}	12.00^{a}	9.33^{e}	12.75^{abc}	10.50^{abc}	9.75^{abc}	11.00^{bc}
85259	13.13^{abcd}	7.50^{f}	6.00^{e}	8.87^{gh}	13.13^{abc}	11.50^{abc}	10.50^{ab}	11.71^{ab}	8.50^{f}	11.10^{abc}	9.75^{abc}	9.78^{cde}
85257	11.25^{d}	10.88^{bcde}	7.50^{de}	9.87^{gf}	11.25^{c}	13.00^{a}	9.00^{b}	11.03^{bcd}	10.00^{def}	10.20^{bc}	9.00^{bc}	9.73^{cde}
971	13.13^{abcd}	10.88^{bcde}	10.50^{bc}	11.50^{cde}	13.13^{abc}	12.00^{ab}	10.50^{ab}	11.88^{ab}	11.50^{abcd}	9.00^{c}	7.50^{c}	9.33^{e}
744	12.75^{abcd}	11.25^{abcde}	10.50^{bc}	11.50^{cde}	12.75^{abc}	11.00^{abc}	9.00^{b}	10.92^{bcde}	10.50^{cdef}	11.40^{abc}	9.00^{bc}	10.30^{cde}
75227	12.50^{bcd}	12.75^{ab}	10.50^{bc}	11.92^{abcde}	12.50^{abc}	10.00^{bc}	6.00^{c}	$9.50d^{e}$	12.00^{abcd}	12.90^{a}	10.50^{ab}	11.80^{ab}
L1	12.50^{bcd}	13.50^{a}	12.75^{ab}	12.92^{ab}								
L2	12.38^{bcd}	12.00^{abcd}	13.50^{a}	12.63^{abc}								
L3	13.75^{bca}	2.49^{abcd}	13.50^{a}	13.08^{a}								
LSD	2.45	2.55	2.49	1.37	2.51	2.5	2.5			2.5		
0.05								1.72	2.41		2.5	1.37
CV (%)	11.81	13.64	14.13	12.9	12.06	13	15.81	16.6	13.05	13.9	15.64	13.97

Mean values showed by the same letter(s) within a column are not significantly different from each other.

4.6 Body

There was highly significant (($P \leq 0.001$) variation of coffee accessions on the body in the case of Awada (Appendix 1a).The coffee accession 9718 had the highest medium full to full body while accession 85259 showed the lightest to medium body 9table 7). The correlation analysis clearly showed that body had significant ($P \leq 0.05$) and positive relationship with shape and make (r = 0.22**), color (r = 0.22**), acidity (r = 0.59***), character (r = 0.56***) roast volume increment (r = 0.44**), screen (r = 0.41***), bean weight (r = 0.42***) and with total quality (r =. 46***) (Appendix 4).

At Korke, the coffee accessions had highly significant ($P \leq 0.001$) variation in body(Appendix 1b).Accession 9718 fall in the range varying from medium full to full body while accession 75227 had least light to medium body (Table 7). Similarly, body was significantly ($P \leq 0.05$) and positively correlated with roast weight loss (r = 0.20*), character (r = 0.52***), shape and make (r = 0.35***), color (r = 0.35***), roast volume increment (r = 0.38***), bean weight (r = 0.31***) and total quality (r = 0.47***) (Appendix 5). At Konga, there was no significant variation ($P \geq 0.05$) among coffee accessions observed. However, there was significant ($P \leq 0.05$) and positive correlation with acidity (r = 0.53***), character (r = 0.62***), roast volume increment (r = 0.28***), roast weight loss (r = 0.48***), screen (r = 0.18***), bean weight (r = 0.55***) and with total quality (r = 0.37) and with color (r = 0.22*) (Appendix 6).

At Awada, wet processed accession 9718 showed medium full to full with a mean value of 13, which was followed by local landrace L3 and accession 9722, which had medium full body with a mean value of 12.5 and 12, respectively. On the other hand coffee accession 85294 with

a light body with a mean value of six. Accession 9718, 9722, and 9744 when subjected to sun drying.. The least body was obtained for 85259, representing a medium body. But, under semi-washed processing, accessions 9744 and 85237 showed medium full body ,followed by 979 with a medium to medium full body having a mean value of 11.63 (Table 7).

At Korke, the data presented in Table 7 clearly showed that wet processed coffee accessions 9718 and 1377 had medium full body where the minimum value was seven, which was for accession 85257 The value of body increased under sun dried processing method. Under this method, accession 9718 and 85294 had the highest mouth full body with a mean value of 15 and a medium body observed by accession 75227 with a mean value of nine.

Sun dried coffee harvested from Konga showed the highest full body when compared to wet processing. Under this accession 9722 and 9744 recorded as the best in their body with a mean value of 14.5The least light to medium body recorded as 9.25 by accession 85238. Under wet processing method, the highest body recorded as 11.25 by accession 85237. The least recorded as 9.33 by accession 85259.The result agreed with Agawanda (1999) in that acidity and body for their suitability as a selection criterion for the genetic improvement of over all liquor quality and there was variation in their body among genotypes of *Coffee arabica* (Yigzaw, 2006). Davids (2001), and Bacon (2005) also reported that dry processed (natural) have a full body and natural sweetness of the beans.

Table 7. The effect of processing method on the coffee brew body at different locations

Coffee genotype	Sidama(Awada)				Sidama(Korke)				Yirgacheffee(Konga)			
	Wet	Semi-washed	Sun dried	Average	Wet	Semi-washed	Sun dried	Average	Wet	Semi-washed	Sun dried	Average
85238	10.25^{bcd}	9.00^{cd}	13.50^{a}	9.91^{ef}	9.25^{bc}	10.00^{ab}	11.63^{b}	10.29^{bc}	9.50^{a}	9.60^{ab}	9.25^{f}	9.45^{c}
9718	8.00^{def}	11.25^{abc}	14.25^{a}	12.83^{a}	12.00^{a}	12.00^{a}	15.00^{a}	13.00^{a}	10.16^{a}	10.20^{ab}	13.00^{b}	11.12^{abc}
85237	8.75^{dec}	12.75^{a}	13.50^{a}	11.66^{abcd}	10.25^{ab}	10.00^{ab}	11.25^{bc}	10.50^{bc}	11.25^{a}	9.60^{ab}	11.5^{cd}	10.88^{abc}
974	11.00^{abc}	9.75^{bcd}	13.50^{a}	11.42^{bcd}	10.25^{ab}	10.00^{ab}	9.00^{c}	9.75^{cd}	11.00^{a}	10.50^{ab}	12.25^{bc}	11.25^{abc}
1377	11.00^{abc}	9.75^{bcd}	12.00^{abc}	10.92^{de}	8.00^{bc}	11.00^{ab}	12.75^{ab}	10.58^{bc}	9.91^{a}	10.20^{ab}	10.00^{ef}	10.04^{bc}
9744	11.25^{ab}	12.75^{a}	14.25^{a}	12.75^{ab}	9.00^{bc}	12.00a	10.50^{bc}	10.50^{bc}	12.00^{a}	11.70a	14.50^{a}	12.73^{a}
979	11.00^{abc}	11.63^{ab}	12.00^{abc}	11.54^{abcd}	10.25^{ab}	11.00^{ab}	12.75^{ab}	11.33^{b}	11.00^{a}	10.20^{ab}	13.00^{b}	11.57^{ab}
9722	12.00^{ab}	11.25^{abc}	12.00^{abc}	12.50^{abc}	10.25^{ab}	12.50^{a}	11.00^{bc}	11.25^{b}	11.42^{a}	9.00^{b}	14.50^{a}	11.64^{ab}
85294	6.00^{f}	10.50^{abc}	11.00^{bcd}	9.17^{fg}	12.00^{a}	11.50^{ab}	11.00^{bc}	12.83^{a}	10.75^{a}	9.90^{a}	11.50^{cd}	10.72^{bc}
85259	13.00^{a}	7.50^{d}	9.00^{d}	8.17^{g}	8.00^{bc}	11.50^{ab}	11.00^{bc}	10.50^{bc}	9.33^{a}	10.20^{ab}	11.50^{cd}	10.34^{bc}
85257	7.00^{ef}	10.50^{abc}	10.50^{ed}	9.33^{fg}	7.00^{c}	11.00^{ab}	11.00^{bc}	9.67^{cd}	10.17^{a}	9.00^{b}	10.75^{de}	9.97^{bc}
971	10.25^{bcd}	11.25^{abc}	12.75^{abc}	11.42^{bcd}	9.00^{bc}	11.00^{ab}	11.00^{bc}	10.75^{bc}	10.33^{a}	9.00^{b}	11.50^{cd}	10.28^{bc}
744	10.25^{bcd}	11.25^{abc}	14.25^{a}	11.27^{cd}	9.00^{bc}	11.00^{ab}	11.00^{bc}	10.67^{bc}	10.00^{a}	10.20^{ab}	11.50^{cd}	10.57^{bc}
75227	10.50^{bc}	11.25^{abc}	13.13^{ab}	11.62^{abcd}	8.25^{abc}	9.00^{b}	11.00^{bc}	8.75^{d}	10.00^{a}	11.40^{ab}	13.00^{b}	11.47^{ab}
L1	11.25^{ab}	10.88^{abc}	12.00^{acb}	11.38^{cd}								
L2	10.50^{bc}	9.75^{bcd}	10.50^{cd}	11.25^{cde}								
L3	12.50^{ab}	10.50^{abc}	12.75^{abc}	11.92^{abcd}								
LSD(0.05)	2.35	2.55	2.49	1.35	2.51	2.5	2.5	1.32	5.29	2.51	1.44	1.95
CV (%)	13.71	14.38	11.76	13.01	15.82	13.38	12.73	13.14	30	14.89	7.22	19.18

Figures followed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.7 Roast volume

Coffee accessions demonstrated high significant ($P \leq 0.001$) variation in roast volume increment at Awada (Appendix 1). Consequently, the highest volume increment was determined for local landrace (L3), whereas accession 85259 had the least roast volume increment (Table 8). The results also revealed that roast volume increment was highly significantly ($P \leq 0.05$) correlated with acidity (r=0.29), body (r = 0.44), character (r = 0.31) (Appendix 4)

Similarly, significant ($P \leq 0.001$) difference was found among accessions (Appendix 2) at Korke. Thus, the highest mean roast volume increment was recorded for accession 5294. The least increment was recorded for 9722 (Table 8). Again, after roast volume increment was significantly ($P \leq 0.05$) and positively correlated with shape and make (r = 0.37), color (r = 0.31), acidity (r = 0.33), body (r = 0.38), character (r = 0.20), roast weight loss (r = 0.35), screen (r = 0.33), bean weight (r = 0.39) and with total quality (r = 0.23) (Appendix 5).

At Konga, highly significant ($P \leq 0.05$) variation was determined among coffee accessions in roast volume increment (Appendix 3). As a result, the highest result was recorded from 9718 as opposed to the least volume increment from 85237 (Table 8). With regard to the effect of processing techniques, the highest volume increment was recorded for the landrace L_2 with a mean value of 57.33. In a contrast, the least volume increment was recorded for the wet processed 974. The result also depicted very high significant roast volume increment under sun dried processing where accession 1377 had the highest result as opposed to 85259 (Table 8).

At Korke, among accession in roast volume under the wet processing method the highest roast volume increment recorded by accession 85238, 744, and the least by 9722. However, under sun dried processing highest roast volume was observed for accession 9744 (Table 8).

Similarly, at Konga, under wet processing, among accessions, 971 showed 51volume increment, followed by accession 9718 and 9744. The least after roast volume increment was found for 85237 with a mean value of 35. However, under sun dried processing highest roast volume increment was observed for accession 1377. Contrarily, the least volume increment was determined from 85259 with an average value of 18 (Table 8). The result agrees with Clifford (1985) who explained this due to its partial escape for the loss of dry matter and the difference is due to vapor (CO_2) production, vapor (CO_2) retention; vapor (CO_2) expansion; resistance of the cell wall complex to tensile stress.

Table 8. The effect of processing method on the coffee roast volume increment at different locations

Coffee genotype	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
	Wet	**Semi-washed**	**Sun dried**	**Mean**	**Wet**	**Semi-washed**	**Sun dried**	**Mean**	**Wet**	**Semi-washed**	**Sun dried**	**Mean**
85238	37.00^{cde}	43.50^{abc}	50.00^{abc}	43.50^{abcd}	50.00^{a}	37.50^{ab}	34.00^{b}	42.00^{abcd}	38.00^{a}	40.00^{a}	30.00^{bed}	36.00^{cde}
9718	40.00^{bcd}	30.00^{cde}	20.00^{ef}	30.00^{efg}	45.00^{abc}	33.75^{b}	31.00^{b}	38.00^{bcd}	50.00^{a}	44.50^{a}	44.00^{ab}	46.17^{a}
85237	30.00^{cdefg}	40.50^{abcd}	51.00^{abc}	40.50^{cd}	40.00^{abc}	31.87^{b}	31.00^{b}	35.50^{cd}	35.00^{a}	30.00^{a}	20.00^{cd}	28.33^{e}
974	10.00^{h}	35.00^{bcde}	52.00^{ab}	35.00^{defg}	32.00^{bc}	37.00^{ab}	44.00^{b}	38.00^{bcd}	38.00^{a}	33.00^{a}	34.00^{abcd}	35.00^{cde}
1377	43.00^{abc}	48.50^{ab}	54.00^{a}	48.50^{abc}	42.00^{abc}	33.25^{b}	32.00^{b}	37.00^{cd}	39.00^{a}	44.00^{a}	46.00^{ab}	43.00^{abc}
9744	15.00^{gh}	26.00^{de}	37.00^{bdc}	26.00^{hg}	37.00^{abc}	39.50^{ab}	45.00^{b}	41.00^{abcd}	50.00^{a}	35.50^{a}	34.00^{abcd}	39.83^{abcd}
979	37.00^{cde}	28.00^{cde}	19.00^{ef}	28.00^{fhg}	34.00^{abc}	36.50^{ab}	42.00^{b}	38.00^{bcd}	40.00^{a}	40.50^{a}	47.00^{a}	42.50^{abc}
9722	21.00^{efgh}	29.50^{cde}	38.00^{abcd}	29.50^{efg}	30.00^{c}	16.25^{c}	12.00^{c}	21.00^{e}	45.00^{a}	40.00^{a}	50.00^{a}	45.00^{ab}
85294	25.00^{defgh}	37.00^{abcd}	49.00^{abc}	37.00^{fde}	35.00^{abc}	49.37^{a}	62.00^{a}	48.50^{a}	40.00^{a}	35.50^{a}	36.00^{abc}	37.17^{abcde}
85259	20.00^{fgh}	19.00^{e}	18.00^{f}	19.00^{h}	40.00^{abc}	36.25^{ab}	38.00^{b}	39.00^{bcd}	40.00^{a}	39.00^{a}	38.00^{ab}	39.00^{abcd}
85257	43.00^{abc}	41.50^{abcd}	40.00^{abcd}	41.50^{bcd}	40.00^{abc}	31.25^{b}	30.00^{b}	35.00^{d}	42.00^{a}	37.00^{a}	34.00^{abcd}	37.67^{abcd}
971	18.00^{gh}	26.50^{cde}	80.00^{a}	26.50^{hg}	45.00^{bac}	41.87^{ab}	44.00^{b}	44.50^{abc}	51.00^{a}	42.50^{a}	40.00^{ab}	44.50^{ab}
744	35.00^{cdef}	37.50^{abcd}	40.00^{abcd}	37.50^{ed}	50.00^{a}	43.75^{ab}	44.00^{b}	47.00^{ab}	47.00^{a}	42.00^{a}	34.00^{abcd}	41.00^{abcd}
75227	24.00^{defgh}	26.00^{de}	28.00^{dc}	26.00^{hg}	48.00^{ba}	33.62^{b}	29.00^{b}	38.50^{bcd}	46.00^{a}	33.00^{a}	18.00^{d}	32.33^{de}
L1	30.00^{cdefg}	37.50^{abcd}	45.00^{abc}	37.50^{de}								
L2	57.33^{a}	50.33^{ab}	43.33^{abcd}	50.33^{ab}								
L3	55.00^{ab}	52.50^{a}	50.00^{abc}	52.50^{a}								
LSD (0.05)	16.55	17.18	16.75	9.26	16.72	14.88	16.72	9.14	16.72	16.99	16.25	9.26
CV (%)	30..85	28.84	25.27	27.67	24.64	29.06	27.02	25.13	23.29	26	27.31	25.24

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4. 8 Roast weight loss

The result show significant (P≤0.001) variation among accessions evaluated at Awada (Appendix 1). Accordingly, the highest weight loss after roast was recorded from 979 with a loss of 26g, the least weight loss being from accession 9718 (Table 9). In addition after roast weight loss had very highly significantly (P≤0.05) relationships with coffee quality attributes such as with shape and make (r = 0.39), acidity (r = 0.38), bean weight (r = 0.29) and significantly correlated with screen (r = 0.18) and total quality (r = 19) (Appendix 4).

Similarly, highly significant (P≤0.001) variation was obtained in roast weight loss at Korke (Appendix 2). The highest after roast weight loss of 24 g was recorded for roasted 9722, while 9722 had the least weight loss of 16.7g (Table 9). At this site, roast weight loss revealed significantly (P≤0.05) and positively associations with body (r=0.20), and highly significantly with character (r = 0.23), bean weight (r = 0.25), acidity (r = 0.39) and after roast volume increment (r = 0.35) (Appendix 5).

At Konga, accessions exhibited very highly significant difference for weight loss (Appendix 3) and the highest and the lowest values were determined for accessions 971 1377, respectively (Table 9). This parameter was significantly (P≤0.05) and positively correlated with acidity (r = 0.35), body (r = 0.43), roast volume increment (r = 0.45), bean weight (r = 0.48) and significantly (P≤0.05) and positively correlated with color (r = 0.24) and significantly with screen (r = 0.21) (Appendix 6).

Under wet processed genotypes from Awada, Accession 85237 had the highest weight loss of 21 g.The least weight loss (14.9 g) was recorded for genotype 85238 (Table 9). At Korke, under sun dried processing accession 974 had the highest weight loss of 25g, the least was being from accession 744 (Table 9). Like wise, at Konga, under wet processed coffee accessions, genotype 979 showed the highest roast weight loss of 23.2g. This was in contrast to the least loss (13.4 g) for genotype 9744. In addition, among accessions when sun dried, accession 85238 had the highest roast weight loss as opposed to the least weight loss from 1377 (Table 9). The present finding supports Clifford (1985) who reported acceptable dry matter loss within the ranges between 35 and 14% with pale to dark roast.

Table 9 The influence of processing method on the coffee roast weight loss at different study areas

	Sidama (Awada)				**Sidama (Korke)**				**Yirgacheffee (Konga)**			
Coffee genotype	Wet	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**
85238	25.00^{c}	20.41^{cdefg}	31.00^{b}	20.42^{c}	21.90^{dc}	19.77^{abc}	19.70^{d}	20.80^{abc}	16.30^{cde}	24.45^{a}	32.00^{a}	20.53^{abc}
9718	16.20^{d}	14.76^{h}	32.00^{b}	14.76^{e}	20.50^{dc}	17.87^{abc}	17.50^{de}	19.00^{cd}	18.00^{bcde}	21.25^{a}	29.00^{ab}	20.42^{abcd}
85237	25.00^{c}	23.95^{abcde}	22.90^{dc}	23.95^{b}	22.40^{dc}	19.99^{abc}	25.50^{c}	21.07^{abc}	19.60^{abc}	19.20^{ab}	16.00^{gh}	18.27^{cd}
974	30.00^{b}	25.25^{abc}	30.70^{b}	25.25^{b}	21.70^{dc}	23.01^{a}	36.00^{a}	23.35^{a}	18.70^{abcd}	20.35^{ab}	19.00^{efg}	19.35^{cd}
1377	14.80^{d}	16.40^{gh}	24.90^{cd}	16.40d^{e}	18.60^{d}	15.97^{bc}	15.60^{de}	17.10^{d}	14.50^{de}	15.80^{b}	13.00^{h}	14.43^{e}
9744	25.50^{c}	20.62^{cdefg}	20.90^{de}	20.62^{c}	23.00^{cd}	15.06^{c}	12.90^{e}	16.78^{d}	13.40^{e}	20.13^{ab}	19.60^{efg}	17.71^{d}
979	30.00^{b}	25.00^{abcd}	30.56^{b}	25.00^{b}	18.90^{d}	16.97^{bc}	12.90^{e}	18.00^{cd}	23.20^{a}	20.80^{ab}	28.00^{abc}	22.17^{ab}
9722	32.10^{ab}	24.30^{abcde}	30.13^{cb}	24.30^{b}	21.20^{cd}	22.57^{a}	29.00^{bc}	24.10^{a}	14.90^{cde}	20.60^{ab}	20.00^{defg}	18.50^{cd}
85294	31.00^{b}	26.00^{ab}	33.00^{b}	26.00^{ab}	28.70^{ba}	20.75^{ab}	25.60^{bc}	21.00^{abc}	17.50^{bcde}	21.37^{a}	23.00^{cdef}	20.21^{abcd}
85259	30.20^{b}	23.60^{bcdef}	24.30^{d}	23.60^{b}	22.90^{dc}	22.83^{a}	30.57^{b}	23.45^{a}	18.90^{abcd}	22.20^{a}	21.50^{def}	20.87^{abc}
85257	22.10^{c}	18.70^{fgh}	25.10^{ed}	18.70^{dc}	30.00^{ab}	22.33^{a}	30.43^{bc}	22.97^{ab}	17.40^{cde}	21.25^{a}	22.00^{def}	19.55^{cd}
971	36.00^{a}	28.62^{a}	21.30^{de}	28.61^{a}	33.30^{a}	21.22^{ab}	18.90^{d}	23.00^{ab}	22.50^{ab}	24.05^{a}	24.00^{cde}	22.52^{a}
744	24.40^{c}	20.20^{defg}	32.50^{b}	20.20^{c}	30.00^{ab}	18.00^{abc}	16.50^{de}	19.50^{bcd}	14.90^{cde}	22.12^{a}	25.00^{cbcd}	19.59^{cde}
75227	21.60^{c}	19.80^{efg}	41.20^{a}	19.80^{c}	25.30^{bc}	19.94^{abc}	26.30^{bc}	20.75^{abc}	19.50^{abcd}	19.50^{ab}	18.00^{fgh}	19.00^{cd}
L1	32.00^{ab}	24.00^{abcde}	23.90^{d}	24.00^{b}								
L2	22.70^{c}	20.20^{defg}	17.70^{e}	20.20^{c}								
L3	15.50^{d}	16.80^{gh}	18.10^{e}	16.80^{de}								
LSD	4.91	5.01	5.4	2.7	5.02	5.33	5.01	3.51	5.02	5.21	5.1	2.79
CV (%)	11.57	13.89	15.73	13.32	16.03	18.9	13.07	18.03	16.84	14.95	114.68	15.23

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.9 Bean size

Coffee samples collected from Awada evaluated for the Sidama type, revealed significant variation ($P \leq 0.001$) among coffee accessions in bean size (Appendix 1). Accordingly, the highest bold and large bean size was recorded in accession 9744 in which 99% of the beans retained above screen. On the other hand accession 744 had the smallest bean size with 83% of the beans retained above the screen (Table 10). Similarly significant variation ($P \leq 0.05$) was noted among coffee accessions at Korke (Appendix 2).The highest bold and large bean size was recorded from 75227 in which 97% of the beans retained above the screen. The smallest bean size was found for genotype 85259, in which 86% of the beans retained above screen (Table 10). At Konga, significant variation ($P < 0.001$) was also determined among accessions for bean screen size (Appendix 3). The highest bold and large bean size was recorded from 9722, in which 96% of the beans retained above the screen. On the contrary, the smallest screen bean size was determined from 85294, in which above 87% of the beans were retained above screen (Table 10).

Coffee accession from Awada revealed that bean size was significantly ($P \leq 0.05$) correlated with shape and make (r = 0.52), color (r = 0.24), acidity (r = 0.535), body (r = 0.40), character (r = 0.49), bean weight (r = 0.64) and with total quality (r = 0.38) (Appendix 4). Again, at Korke bean size was significantly ($P \leq 0.05$) correlated with shape and make (r = 0.18*), cidity (r = 0.30), and after roast volume increment (r = 0.45) (Appendix 5). Likewise, screen size of the bean at Konga significantly ($P \leq 0.05$) and positively correlated with shape and make (r = 0.22), character (r = 0.33), after roast weight loss (r = 0.21), significantly ($P \leq 0.01$) correlated

with color (r = 0.27), after roast volume increment (r = 0.28) and very highly significantly correlated with bean weight (Appendix 6).

Coffee genotypes showed significant variation (P<0.001) for the bean size under each processing. Among accessions studied at Awada, 9744 had the highest very bold bean with a mean value of 100, followed by 9722 and 971, which had bold and large bean size with 99% of the bean retained above screen 14. In contrast, the smallest bean size was recorded from 744 under both natural sun drying and wet processing methods with a value of 84 and 82, respectively (Table 10).

At Korke, significant (P≤0.001) difference was observed among the accession. Consequently, the wet processed 75227 exhibited maximum bold bean where 99 % of the beans were retained above the screen 14. However, accession 85259 and 85294 had smaller beans and only 86% of the beans were retained above screen 14. Similar result was obtained from the sun dried cultivar 75227 where 95% of the beans retained above the screen 14. Whereas smaller bold bean was measured for 85259 and 85294 with 85% of the beans retained on above screen 14 (Table 10).

At Konga, among accessions when wet and dry processed, accordingly, the washed accession 85257 showed bold bean with more than 97 % of the beans retained above screen. Nonetheless, 979 were noted to have the smallest bean size with 85% the beans retained above the 14 screen. On the other hand, accessions the sun dried 9722 and 85257 were characterized by having bold beans with the corresponding 98 and 97% of the beans retained above screen

14. Accession 85294 was found to have medium to small beans, in which 88% of the beans retained above screen 14 (Table 10).These result agrees with Yigzaw (2006), Sivetz and Dosrosier (1979) and EAFCA (2008), who reported that bean size is determined by screening that has a particular importance to roasters since bean size would be exposed to roast uniformly, which is influenced by botanical variety and environmental growth circumstances.

Table 10. The influence of processing method on the coffee bean size at different locations

Coffee genotype	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
	Wet	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**
85238	92.00^{cde}	93.50^{cd}	95.00^{abcd}	93.50^{de}	93.00^{bc}	90.50^{bc}	90.00^{bcd}	91.50^{de}	94.00^{ab}	93.60^{ab}	94.20^{abc}	93.93^{abc}
9718	96.00^{abc}	96.50^{abc}	97.00^{abc}	96.50^{cd}	92.00^{cd}	88.87^{dc}	88.00^{dc}	90.00^{e}	92.00^{bc}	94.00^{ab}	96.00^{ab}	94.00^{abc}
85237	96.00^{abc}	97.50^{abc}	99.00^{c}	97.50^{ab}	95.00^{ab}	93.75^{ab}	94.00^{ab}	94.50^{b}	87.00de	95.25^{ab}	95.50^{ab}	92.58^{bcd}
974	99.00^{a}	94.00^{bcd}	99.00^{c}	94.00^{de}	87.00^{de}	90.12^{bc}	93.00^{ab}	90.00^{e}	89.00^{cde}	91.50^{bc}	96.00^{ab}	92.17^{bcd}
1377	97.00^{ab}	97.50^{abc}	89.00^{ef}	97.50^{ab}	95.00^{ab}	91.25^{bc}	90.00^{bcd}	92.50^{bcd}	91.00^{bcd}	95.37^{ab}	95.75^{ab}	94.04^{abc}
9744	100.00^{a}	99.00^{a}	98.00^{ab}	99.00^{a}	94.00^{bc}	93.37^{ab}	94.00^{ab}	94.00^{bc}	95.00^{ab}	94.00^{ab}	94.00^{abc}	94.33^{ab}
979	92.00^{cde}	94.50^{bcd}	97.00^{abc}	94.50^{cd}	90.00^{cde}	90.62^{bc}	92.00^{abc}	91.00^{de}	85.00^{e}	93.50^{ab}	97.00^{ab}	91.83^{cd}
9722	99.00^{a}	98.00^{ab}	97.00^{abc}	98.00^{ab}	95.00^{ab}	91.87^{bc}	91.00^{abc}	93.00^{bcd}	94.00^{ab}	96.50^{a}	98.00^{a}	96.17^{a}
85294	85.00^{hg}	85.00^{e}	85.00^{fg}	85.00^{g}	86.00^{e}	85.37^{d}	86.00^{c}	86.00^{f}	87.00de	87.00^{d}	88.00^{d}	87.33^{f}
85259	97.00^{ab}	94.50^{bcd}	92.00^{de}	94.50^{cd}	86.00^{e}	85.37^{d}	86.00^{d}	86.00^{f}	89.00^{cde}	88.50^{dc}	91.00^{de}	89.50^{ef}
85257	94.00^{bdc}	93.50^{cd}	93.00^{cde}	93.50^{de}	91.00^{bcd}	91.62^{bc}	93.00^{ab}	92.00^{cde}	97.00^{a}	94.00^{ab}	97.00^{ab}	96.00^{a}
971	99.00^{a}	99.00^{a}	99.00^{e}	99.00^{a}	90.00^{cde}	91.25^{bc}	93.00^{ab}	91.50^{de}	86.00^{e}	93.50^{ab}	97.00^{ab}	92.17^{bcd}
744	82.00^{h}	83.00^{e}	84.00^{g}	83.00^{g}	92.00^{bc}	90.12^{bc}	90.00^{bcd}	91.00^{de}	91.00^{bcd}	93.50^{ab}	95.00^{abc}	93.17^{bcd}
75227	87.00^{gh}	92.00^{d}	97.00^{abc}	92.00^{ef}	99.00^{a}	95.87a	95.00^{a}	97.00^{a}	85.00^{e}	96.00^{a}	93.00^{bc}	91.33^{de}
L1	90.17^{def}	90.58^{d}	93.00^{cde}	90.00^{f}								
L2	90.167^{def}	92.08^{d}	94.00^{bed}	92.01^{ef}								
L3	89.33^{ef}	91.17^{d}	93.00^{cde}	91.12^{f}								
LSD(0.05)	4.03	4.14	4.01	2.24	4.18	3.69	4.81	2.27	4.18	4.24	4.18	2.31
CV (%)	2.59	2.66	2.55	2.56	2.72	2.84	2.82	2.64	2.77	2.71	2.63	2.66

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.10 Bean weight

The bean weight of coffee accessions harvested from Awada was highly influenced by both coffee genotype and processing methods treatments, (Table 11).The bean weight of accession 85237 was found to be heavier than that of bean weight of accession 85238. The coffee accession 85237 was found to be the heaviest when compared with all the other coffee accessions grown under Awada agro climatic conditions. The sun dried 75227 and 9718 weighted 19 and 18 g, respectively, and are considered as heavy beans. Coffee accession 85257 weighted 13.5 and characterized as light bean (Table 11). In addition, bean weight significantly ($P \leq 0.001$) differs among accessions at Korke. Under wet processing, the medium bean weight was recorded for coffee accession 1377, 979 and 744 subjected to wet processed. whereas, accession 85259 was found to have light beans with a mean bean weight of 13.4g (Table 11). Bean weight showed highly significant ($P \leq 0.05$) associations with quality parameters such as shape and make ($r = 0.49$), color ($r = 0.37$), acidity ($r = 0.44$), body ($r = 0.42$), character ($r = 0.29$), screen size of the bean ($r = 0.46$) and with total quality ($r = 0.41$) (Appendix 4).

At Korke, the bean weight was highly influenced (($P \leq 0.001$) with the pre harvest treatment of coffee genotypes. Among the coffee accessions, 974 had the heaviest beans with a mean weight of 18.4g while accession 85259 was the lightest with mean bean weight of 13.1g. Regarding the relationship between bean weight and coffee quality at Korke, the correlation was found to highly significant ($P \leq 0.05$) and positively with body ($r = 0.31$), roast volume increase ($r = 0.39$), screen ($r = 0.47$), with roast weight loss ($r = 0.25$) (Appendix 5).

Similarly, bean weight revealed significantly (P≤0.05) affected by coffee accessions (Appendix 3) at Konga. The heaviest bean weight was recorded for 979 with a mean bean weight of 16.16g. On the other hand, coffee accession 85294 had light bean weight of 12.78 g (Table 11). Similarly, bean weight was significantly (P≤0.05) and positively correlated with shape and make (r = 0.53), color (r = 0.62), acidity (r = 0.48), body (r = 0.55), character (r = 0.31), after roast volume increase (r = 0.57), roast weight loss (r = 0.48), screen (r = 0.50) and total quality (r = 0.54) (Appendix 6).

At Konga, where the wet processed accession 979 showed medium to heavy beans and accession 744 had light beans with a value of 12.4g (Table 12). The result, therefore, indicates the existing heterogeneity among coffee genotypes for bean characteristics. This corroborates with other authors who reported that Arabica varieties (genotypes) were diverse in average bean weight with the values ranging between 18.2 g and 9.2g (Wintegens, 2004; Yigzaw, 2006).

Table 11. Bean weight as affected by the various processing methods at the three study areas

	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
Coffee genotpe	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washed**	**Sun dried**	**Average**
85238	14.90^{g}	15.60^{efgh}	16.30^{cde}	15.60^{hg}	14.30^{bcd}	13.55efg	13.60^{ef}	13.95^{d}	13.80^{cd}	13.30^{bcd}	12.30^{ed}	13.13^{f}
9718	16.60^{cdefg}	17.70^{abcd}	18.80^{a}	17.70^{bcd}	15.90^{ab}	15.15^{bcde}	15.20^{cde}	15.55^{bc}	14.20^{abcd}	15.05^{ab}	14.20^{abcd}	14.48^{cde}
85237	21.40^{a}	18.95^{a}	16.50^{bcde}	18.95^{a}	13.60^{de}	15.28^{bcd}	16.80^{bc}	15.20^{c}	15.00^{abc}	14.35^{abcd}	15.10^{abc}	15.02^{abcd}
974	18.30^{bc}	16.40^{cdefg}	14.50^{ef}	16.40^{egf}	15.60^{abc}	18.78^{a}	21.00^{a}	18.40^{a}	14.00^{abcd}	15.35^{ab}	13.90^{bcde}	14.95^{bcd}
1377	17.00^{bcdef}	17.75^{abc}	18.50^{ab}	17.75^{bdc}	16.40^{a}	15.33^{bcd}	15.20^{cde}	15.8b^{c}	14.00^{abcd}	15.15^{ab}	15.90^{ab}	14.35^{de}
9744	19.00^{b}	18.75^{ab}	18.50^{ab}	18.75^{ab}	16.10^{a}	16.22^{bc}	16.80^{cb}	16.45^{b}	14.008^{abc}	16.00^{a}	15.90^{ab}	15.57^{abc}
979	17.00^{bcdef}	17.5^{5abcde}	18.10^{ab}	17.55^{cd}	16.30^{ab}	16.05^{bc}	16.40^{bcd}	16.35^{b}	16.002^{c}	16.20^{a}	16.10^{a}	16.17^{a}
9722	17.90^{bcd}	18.00^{abc}	18.10^{ab}	18.00^{abc}	15.60^{abc}	15.28^{bcd}	15.60^{cde}	15.60^{bc}	15.01^{abc}	15.65^{a}	15.70^{ab}	15.65^{ab}
85294	15.60^{efg}	15.25^{fgh}	14.90^{ef}	15.25^{ih}	13.50^{d}	13.75^{defg}	14.40^{def}	13.95^{d}	13.006^{cd}	12.75^{d}	12.00^{e}	12.78^{f}
85259	17.10^{bcdef}	16.75^{cdefg}	16.50^{bcde}	16.75^{def}	13.40^{d}	12.71^{g}	12.80^{f}	13.10^{d}	14.00^{bdc}	12.85^{dc}	12.30^{de}	13.05^{f}
85257	15.00^{fg}	14.25^{h}	13.50^{f}	14.25^{i}	15.00^{abcd}	14.81^{cdef}	15.20^{cde}	15.10^{c}	15.00^{abc}	15.00^{ab}	15.00^{abc}	15.00^{bcd}
971	17.10^{bcde}	17.10^{abcdef}	17.10^{abcd}	17.10^{cde}	14.00^{abcd}	16.62^{b}	18.40^{b}	16.45^{b}	16.00^{ab}	14.90^{abc}	15.30^{abc}	15.40^{abcd}
744	16.10^{defg}	15.60^{efgh}	15.10^{def}	15.60^{hg}	16.30^{ab}	15.80^{bc}	16.00^{cd}	16.15^{bc}	12.40^{d}	16.05^{a}	15.80^{ab}	14.74^{bcde}
75227	18.50^{cb}	18.75^{ab}	19.00^{a}	18.70^{ab}	13.50^{d}	13.25^{fg}	13.60^{ef}	13.55^{d}	14.00^{bcd}	13.50^{bcd}	13.50^{cde}	13.67^{ef}
L1	15.67^{efg}	15.93^{cdef}	16.00^{cde}	15.93^{hgf}								
L2	16.51^{cdefg}	15.85^{defgh}	15.20^{def}	15.85^{hgf}								
L3	15.30^{efg}	14.95^{gh}	14.60^{ef}	14.95^{hi}								
LSD(0.05)	2.03	2.08	2.07	1.34	2.09	1.71	2.09	1.09	2.09	2.12	2.09	1.16
CV (%)	7.2	7.46	7.43	7.24	8.33	7.87	7.91	7.53	8.59	8.59	8.65	8.47

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.11 Character

Character is a set of coffee quality attribute which make distinctive for that particular variety for the specified origin grown under that particular environment which known and registered. In this work, the treatments were evaluated based on the coffee quality attribute scaling described by Lingle (1986) for coffee character. The results depicted significant ($P \leq 0.05$) differences for the Sidama coffee character at all the study sites (Appendix 1a and 1b). Among the accessions evaluated at Awada, excellent and sweetly spicy, after taste with a balanced and creamy mouth feel sensation was recorded from the local landrace L-3, which was followed by coffee accession 9744 that also had fine sweetly spicy and creamy mouth feel sensation. In addition, coffee accession 9718, L-2, 9722 and 9744 had fine to excellent sweetly spicy mouth feel sensation and thus among the top best genotypes of the Sidama coffee type (Table 12).

The results presented in Table 12 revealed significant variation ($P \leq 0.001$) among coffee genotypes studied at Korke site. Consequently, coffee accession 9718 had very good to fine character with a sweet, spicy mild top Sidama character, followed by 979 with good to very good Sidama type when wet processed. Similar result was found at Konga (Appendix 3), where accession 9744 showed a very good to fine quality with rounded sweetly floral test and followed by 9718 with high acidity and sweetly floral test. The washed genotype 9718 also showed an excellent quality with good positively all rounded character with high acidity related with sweetly floral character. Accession 9744 and 9722 having top sweetly floral balanced flavory cup was noted to be the top for the sun dried Yirgacheffe type, the most inferior was being accession 85257 (Table 13).

The interaction effect due to genotype and location was found to be highly significant ($P \leq 0.05$), indicating the specific performances of the coffee landraces. Accordingly, genotype 9744 had excellent character, followed by 1377 with good to fair for the specific character of sidama type at Awada. At Korke, however, excellent quality character was determined from genotype 9718, followed by 9744 with fair to good. But, genotype 744 had the least quality response at Korke site. Therfore, 9744 and 9718 had wider performance for both Sidama and Yirgacheffe areas as compared with the genotypes (Figure 1). The result agrees with ES (589:2001) in that coffee from Sidama and Gedeo zone in Southern Ethiopia can produce good quality coffee with balanced acidity and body, and sweet to floral test and coffee from Yirgacheffe distinct and its surrounding area has medium to pointed acidity and well-balanced cup of floral test. In addition, coffees from Yirgacheffe and Sidama fetches premium price both at domestic and international market because of its distinctive fine quality (Chifra et al., 1998; ITC, 2002; IPO, 2008).

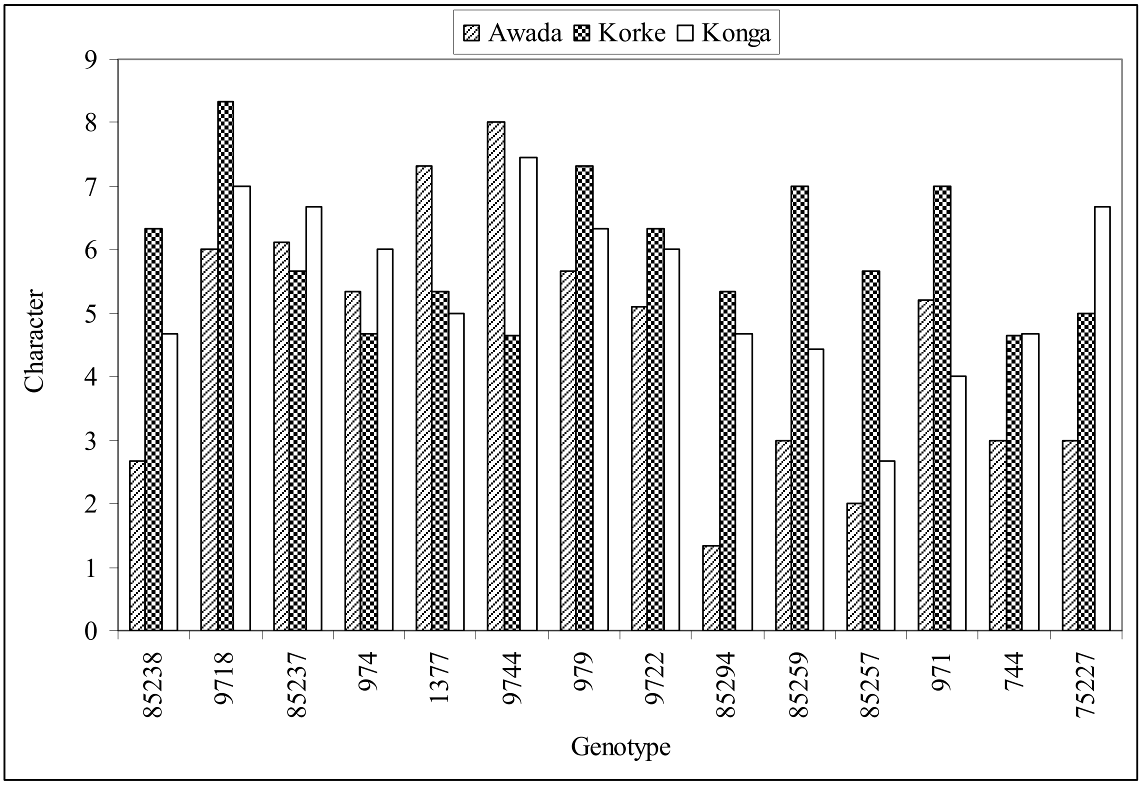

Figure 1. Coffee character of the different genotypes planted at the three study areas.

Table 12. The effect of processing method on coffee character at the different study locations

	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
Coffee genotype	**Wet**	**Semi-washed**	**Sun dried**	**Average**	**Wet**	**Semi-washd**	**Sun dried**	**Average**	**Wet**	**Semi-washd**	**Sun dried**	**Average**
85238	2.00^{ef}	2.00^{ef}	4.00^{e}	2.67^{d}	7.00^{bc}	6.00^{c}	6.00^{cd}	6.33^{bcd}	5.00^{dc}	2.00^{ef}	7.00^{bc}	4.67^{de}
9718	3.00^{de}	6.00^{abc}	9.00^{a}	6.00^{c}	8.00^{ab}	9.00^{a}	8.00^{ab}	8.33^{a}	8.00^{a}	5.00^{bc}	8.00^{ab}	7.00^{ab}
85237	6.00^{c}	5.33^{bc}	7.00^{bc}	6.11^{c}	7.00^{bc}	6.00^{c}	4.00^{fe}	5.67^{cde}	7.00^{ab}	6.00^{ab}	7.00^{bc}	6.67^{abc}
974	6.00^{c}	4.00^{cde}	6.00^{cd}	5.33^{c}	7.00^{bc}	6.00^{c}	1.00^{h}	4.67^{e}	6.00^{cb}	6.00^{ab}	6.00^{dc}	6.00^{c}
1377	9.00^{a}	6.00^{abc}	7.00^{bc}	7.33^{b}	3.00^{e}	6.00^{c}	7.00^{bc}	5.33^{de}	5.00^{cd}	4.00^{cd}	6.00^{dc}	5.00^{c}
9744	800^{ab}	8.00^{a}	8.00^{ab}	8.00^{ab}	3.00^{e}	9.00^{a}	2.00^{gh}	4.67^{e}	6.33^{abc}	7.00^{a}	9.00^{a}	7.44^{a}
979	4.00^{b}	6.00^{abc}	7.00^{bc}	5.66^{c}	9.00^{e}	6.00^{c}	7.00^{bc}	7.33^{ab}	3.00^{abc}	6.00^{ab}	7.00^{bc}	6.33^{bc}
9722	4.00^{b}	5.33^{bc}	6.00^{cd}	5.11^{c}	7.00^{bc}	8.00^{ab}	4.00^{ef}	6.33^{bcd}	7.00^{ab}	2.00^{ef}	9.00^{a}	6.00^{c}
85294	1.00^{f}	1.00^{f}	2.00^{f}	1.33^{e}	6.00^{cd}	1.00^{d}	9.00a	7.00^{abc}	6.00^{bc}	3.00^{de}	5.00^{de}	4.67^{de}
85259	7.00^{bc}	1.00^{f}	1.00^{f}	3.00^{d}	7.00^{bc}	7.00^{bc}	7.00^{bc}	5.33^{de}	5.33^{bcd}	2.00^{ef}	6.00^{dc}	4.44^{de}
85257	1.00^{ef}	3.00^{def}	1.00^{f}	2.00^{de}	5.00^{d}	7.00^{bc}	5.00^{de}	5.67^{cde}	4.00^{d}	1.00^{f}	3.00^{f}	2.67^{f}
971	2.00^{ef}	4.67^{cd}	4.00^{e}	5.20^{c}	7.00^{bc}	7.00^{bc}	7.00^{bc}	7.00^{abc}	7.00^{ab}	1.00^{f}	4.00^{ef}	4.00^{e}
744	7.00^{bc}	3.00^{def}	5.00^{dc}	3.00^{d}	5.00^{d}	7.00^{bc}	3.00^{fg}	4.67^{e}	6.00^{bc}	2.00^{ef}	6.00^{cd}	4.67^{de}
75227	1.00^{f}	2.00^{ef}	6.00^{cd}	3.00^{d}	2.00^{e}	7.00^{bc}	5.00^{de}	5.00^{de}	6.00^{bc}	7.00^{a}	7.00^{bc}	6.67^{abc}
L1	1.00^{f}	7.00^{ab}	7.00^{bc}	7.33^{b}								
L2	8.00^{ab}	7.00^{ab}	8.00^{ab}	7.66^{ab}								
L3	9.00^{a}	8.00^{a}	9.00^{a}	8.66^{a}								
LSD(0.05)	1.63	2.26	1.65	1.03	1.67	1.67	1.67	1.58	1.77	1.67	1.67	0.94
CV (%)	19.47	29.21	17.26	21.48	16.86	15.22	18.6	28.3	17.49	25.92	15.55	18.37

Figures showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.12 Total quality

The total quality of a coffee is the overall quality of the coffee based the overall quality attribute result used to determine and evaluate the quality potential of the coffee variety (genotype). Among coffee accessions and land races evaluated for their total quality based on the combined result of processing methods, for the Sidama type from Awada, significant variation ($P \leq 0.05$) observed among coffee accessions (Appendix 1). Among coffee accessions, 9744 has a very good cup quality with sweet rounded cup with high acidity related with citrus test with a mean value of 86.33 followed by 9718 also have a good cup quality with a mean value of 85.54. Among accessions, 85294 considered the least in the overall total quality from the accessions evaluated (Table 13).

Total quality of the coffee at Awada highly significantly ($P \leq 0.05$) and positively correlated with shape and make ($r = 0.76$), color ($r = 0.67$), acidity ($r = 0.75$), body ($r = 0.46$), character ($r = 0.64$), screen ($r = 0.38$) and bean weight ($r = 0.41$) and roast weight loss (Appendix 4).

Among coffee accessions evaluated for the Sidama type from Korke, significant variation ($P \leq 0.05$) among coffee accessions observed (Appendix 2). Among accessions, 9718 recorded as the top having a good physical as well as cup quality with a sweet balanced cup with a mean value of 83.41 and 85227 considered as the least in the overall physical and cup quality compared with other accessions (Table 13). Total quality of coffee significantly ($P \leq 0.05$) and positively correlated with shape and make ($r = 0.54$), color ($r = 0.52$), acidity ($r = 0.49$), body ($r = 0.47$), character ($r = 0.48$), and roast volume increment ($r = 0.23$) (Appendix 5).

With regard to interaction, genotype by processing method had significant effects on the total quality of Sidama coffee (Appendix 3). Most genotypes showed superior results when wet processed, followed by semi-washed and dry processed in that order (Fig 2). This supports the previous results that indicate the contributions of washed coffee processing in improving the inherent quality coffees (Behailu et al., 2008).

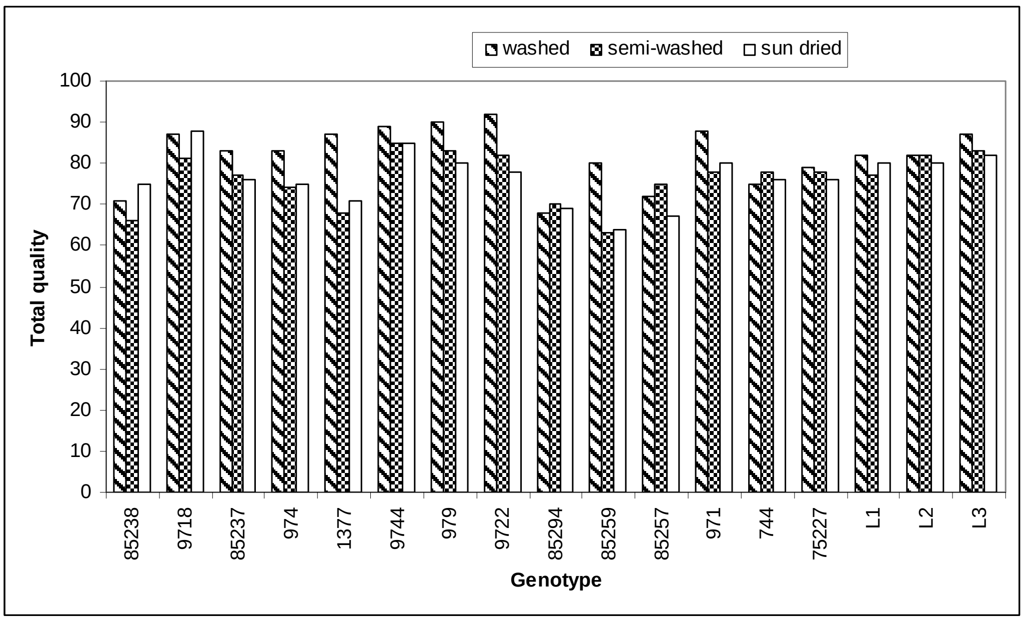

Figure 2. Interaction effect of processing method and coffee genotype on total quality

The results show significant variation ($P \leq 0.001$) among the Yirgacheffe coffee accessions in the total quality (Appendix 3). Thus, 9744 had superior quality with an overall good physical and cup quality, which is a sweet and flavory. However, the least result for both the overall physical and cup quality parameters were detected from 85238 (Table 13). To this end, knowledge of correlation among different characteristics is essential to design an effective breeding program to improve the quality of coffee accessions, especially for Ethiopia where immense genetic diversity is known to exist. Hence, the correlation results indicated that total

quality of coffee at Konga was significantly ($P \leq 0.05$) and positively correlated with the shape and make ($r = 0.59$), color ($r = 0.62$), acidity ($r = 0.53$), body ($r = 0.37$), character ($r = 0.45$), after roast volume increase ($r = 0.43$), bean weight ($r = 0.54$) and with bean size ($r = 0.18$) (Appendix 6).

When evaluating the coffee accessions for their total quality performances under each processing method, at awada for washed Sidama coffees, accession, 9722 had a very good cup quality with sweet rounded cup and high acidity related with citrus character. Genotype 979 and 9744 followed this, which had a good cup quality with a balanced sound cup and mean value of 90 and 89.5, respectively. Under this processing method, the least average total quality value recorded for 85294 (Table 13). The sun dried 9718 had a good cup quality with mouthful complete rounded cup, and flavor with an average value of 88. This was followed by 9744 and L-3 in that descending order for the overall raw and cup quality having sounded flavor and sweet test. In a contrast, the sun dried 85257 and 85259 exhibited the least response when compared to other accessions with a fair to average cup quality and over all physical standards. Under semi- washed processing, accession 9744 and L-3 revealed superior quality for overall raw and cup quality results as opposed to the least accession 85259 (Table 13).

At Korke, significant differences were noted among accessions. The wet processed 9718 had the maximum value of 88.75 with a good physical as well as cup quality and with a sweet balanced cup. This was followed by accession 979 and 9722, which had also good physical and cup quality, with a mean value of 86.75 and 84.75, respectively. Accessions 75227 and 1377 were observed to be among those with the average results for both raw and cup quality

(Table 9). On the other hand, the sun dried 85294 had a good physical and over all cup quality with a value of 84.25, which was followed by 9718 as far their total physical and cup quality are concerned. Under the natural sun drying, 974 and 75227 had an average performance for the overall physical and cup quality as compared to other accessions (Table 14). The same result also observed under the semi-washed processing where 9744 performed best with a value of 80 in the over all total quality. This was in contrast to the CBD resistant selection 75227 with the significantly inferior average value of 65 (Table 13).

Among coffee accessions studied at Konga, the wet processed 85257 had an overall good physical and cup quality as compared to the other with a sweet and flavors tests with a mean value of 83.26. Accessions 85237 and 9717 were placed in the second and third order in terms of the over all-physical and cup quality with a value of 82.88 and 82.75, respectively. Under this processing method, accession 85259 had the least result as compared to other accessions with an average overall total quality of 74.5. Under sundry processing, accession 9722 had a good to a moderately balanced cup with the highest average value of 82.25. This was followed by 9718 with an overall total quality value of 79.25. On the contrary, accession 85238 ranked least with overall quality value of 66 as compared to other accessions (Table 13).

Related result was obtained under semi-washed processing. Accordingly, accession 9744 had the highest total quality on both physical and cup quality. In contrast, accession 85294 was found to be the least in the overall quality as compared with the other accessions (Table 14). Based on the overall quality result, variations were detected among coffee accessions and correlation value between the qualities attributes. This variation was observed for both

physical (raw) and cup quality obtained during the experiment. The result agrees with other findings in which the variation among varieties due to genotype as well as harvest processing method and the environment in which the varieties grown. Moreover, cup quality is a complex characteristic, which depends on various factors such as genetic composition, environment, agronomic practices, ripeness of the fruit and post harvest processing (Moreno et al., 1995; Chifra et al., 1998; Yigzaw, 2006).

Selvakumar and Sreenirasan (1989) reported variations in cup quality ranging from good to excellent among 54 arabica coffee accessions collected from Southwestern (Kaffa province) parts of Ethiopia. There were also significant variations among coffee Arabica accessions collected from different parts of Ethiopia for bean caffeine, chlorogenic acids, sucrose and trigonelline content (Silvarolla et al., 2000, 2004; J ky et al., 2001). Yigzaw (2006), Montagnon and Bouharmont (1996) and Anzueto et al. (2001) reported diversity among Ethiopian coffee genotypes for different agro-morphological characteristics. Therefore, results of this study further confirm the presense of diversity within coffee genotypes for the cup quality characteristics and yield performances of coffee genotypes studied in Southern regions of Sidama and Gedeo zones.

The result also indicated the presence of varaiabilty between the promisng and and local landraces in cup quality as well as bean characteristics for the specific origins of Sidama and Yirgacheffe types. Most accessions were averaged to medium in both physical and cup quality parameters. However, the local landraces and accessions having the highest total quality and characteristic could indicate the availability of genetic resources and can be

maintained for cup quality improvement for both Sidama and Yirgacheffe types. The two coffee selections (744 and 75227) did not well performed in their cup quality for the specified region, requiring further quality research. However, 75227 at Konga site performed well in both total quality and specific character.

The best performed accessions in total quality and characteristics included 9744, 9718, local land races (L3) from Awada and 9718. Among Yirgacheffe genotypes, 9744, 9718 and 9728 were the best, though further investigation is required (Fig 3). These could be used as source of desirable genes for cup quality improvement for each area. The number of accessions with good physical and cup quality attributes was found to be few. This could come due to the differences in the age group among coffee trees used in the research and farmers plots, in which one of the criterions used to select the mother plants for the Sidama type in order to minimize the effect of using the released CBD resistant varieties of 744 and 75227 to the area. In general, the variation in their total quality and character among accessions could be attributed to the difference in genotype as well as environment conditions at each study area.

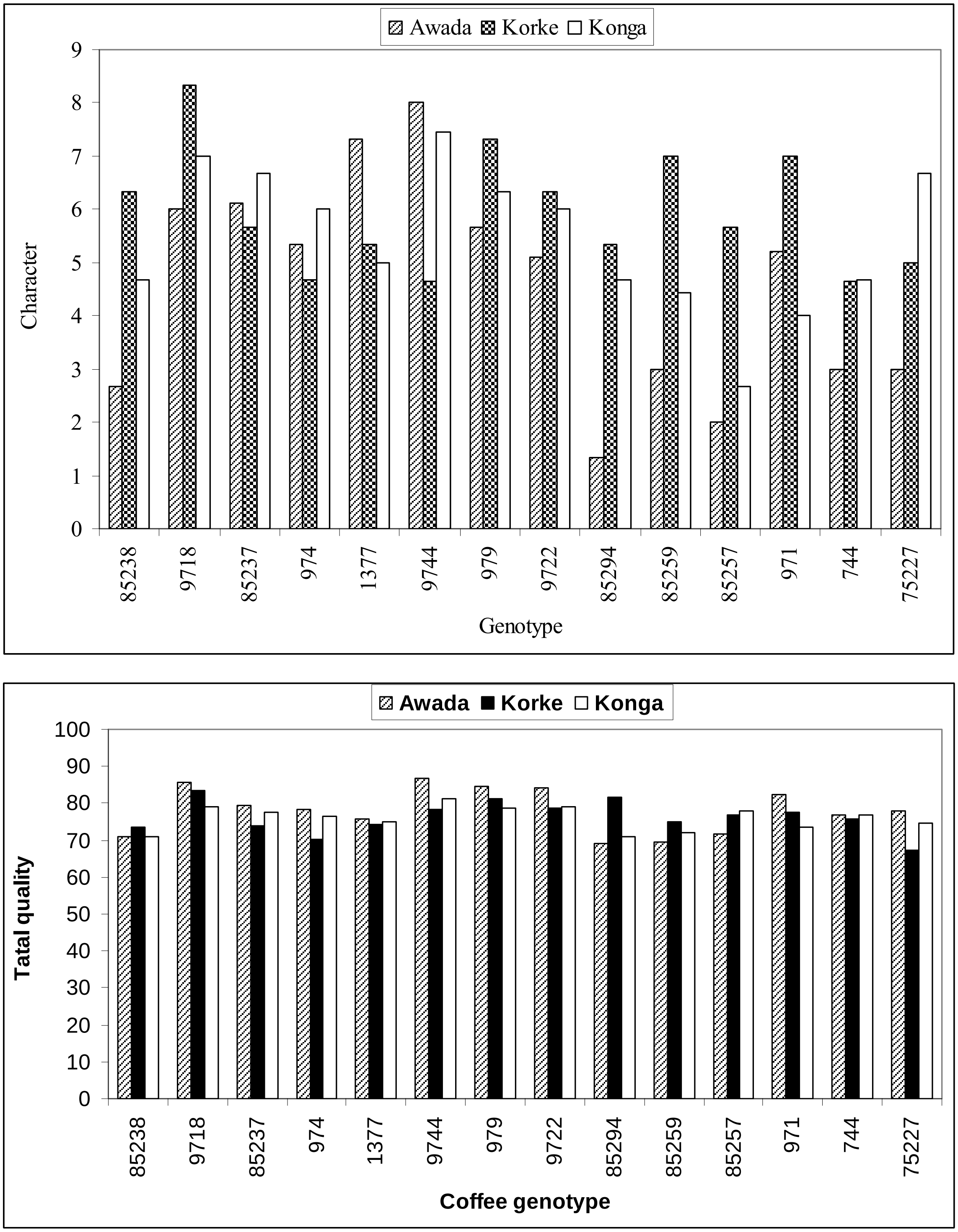

Figure 3. Character and total quality of coffee genotypes at the three study areas

Table 13. The effect of processing method on the total quality of coffee accessions at the study areas

	Sidama (Awada)				Sidama (Korke)				Yirgacheffee (Konga)			
Coffee genotype	Wet	Semi-washed	Sun dried	Average	Wet	Semi-washed	Sun dried	Average	Wet	Semi-washed	Sun dried	Average
85238	71.25^{h}	66.63g	75.25^{e}	71.04^{h}	74.63^{e}	69.00^{f}	77.01^{cde}	73.55^{h}	75.93^{d}	71.00^{ef}	66.00^{g}	71.00^{g}
9718	87.00^{c}	81.63^{b}	88.00^{a}	85.54^{ab}	88.75^{a}	78.00^{abc}	83.50e	83.42^{a}	82.75^{ab}	74.80^{cbd}	79.25^{b}	78.93^{b}
85237	83.63^{d}	77.88^{cd}	76.75^{e}	79.42^{de}	79.88^{d}	70.00^{f}	71.75^{hi}	73.88^{gh}	82.88^{a}	75.70^{b}	74.00^{de}	77.53^{cde}
974	83.75^{d}	74.88^{e}	75.75^{e}	78.12^{ef}	75.00^{e}	69.00^{f}	66.50^{i}	70.17^{i}	81.25^{abc}	75.00^{cbd}	73.25^{de}	76.50^{e}
1377	87.25^{c}	68.50^{fg}	71.75^{f}	75.83^{g}	72.00^{f}	76.00^{dec}	74.75^{efg}	74.25^{gh}	79.13^{c}	75.10^{cbd}	70.25^{ef}	74.83^{f}
9744	89.75^{b}	83.50^{a}	85.00^{ab}	86.83^{a}	81.25^{cd}	80.00^{a}	73.75^{fgh}	78.33^{cd}	82.75^{ab}	82.70^{a}	78.25^{b}	81.40^{a}
979	90.00^{b}	82.76^{ab}	80.50^{d}	84.66^{b}	86.00^{b}	77.50^{abcd}	79.75^{b}	81.03^{b}	80.25^{bc}	77.20^{b}	78.50^{b}	78.65^{bc}
9722	92.75^{a}	82.00^{b}	78.25^{de}	84.33^{b}	84.75^{b}	79.50^{ab}	72.25^{ahi}	78.83^{c}	82.00^{ab}	73.00^{ced}	82.25^{a}	79.08^{b}
85294	68.25^{i}	70.00^{f}	69.50^{fg}	69.25^{i}	83.50^{bc}	77.00^{bcd}	84.25^{a}	81.58^{ab}	75.26^{d}	70.30^{f}	67.75^{fg}	71.10^{g}
85259	89.63^{b}	63.25^{h}	64.75^{h}	69.41^{i}	74.00^{ef}	73.50^{e}	77.50^{bc}	75.00^{fgh}	74.50^{d}	72.70^{def}	68.75^{f}	71.98^{g}
85257	72.75^{h}	75.63^{de}	67.00^{gh}	71.79^{h}	79.25^{d}	80.00^{a}	70.75^{i}	76.67^{def}	83.26^{a}	76.00^{b}	75.50^{c}	77.95^{bcd}
971	88.38^{cb}	78.63^{c}	80.50^{cd}	82.50^{c}	80.75^{d}	75.00^{dc}	77.38^{bcd}	77.71^{cde}	75.25^{d}	71.50^{ef}	74.00^{cd}	73.58^{f}
744	75.75^{g}	83.50^{c}	76.00^{e}	76.67^{gf}	76.50^{e}	76.00^{cde}	74.88^{def}	75.79^{efg}	80.89^{abc}	75.50^{cb}	74.00^{cd}	76.80^{de}
75227	79.75^{f}	85.75^{cd}	76.38^{e}	78.08^{ef}	72.00^{f}	65.00^{g}	65.00^{i}	67.33^{j}	75.00^{d}	75.10^{cbd}	72.75^{de}	74.79^{f}
L1	82.50^{de}	77.13^{cde}	80.50^{cd}	80.04^{d}								
L2	82.38^{de}	78.25^{b}	80.50^{cd}	81.82^{c}								
L3	87.00^{c}	78.13^{ab}	82.17^{bc}	84.22^{b}								
LSD(0.05)	2.36	2.5	3.49	1.55	2.51	2.51	2.51	2.13	2.5	2.51	2.508	1.39
CV (%)	1.72	1.95	2.69	2.11	1.89	2	2	2.97	1.88	2	2.02	1.94

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.13 Coffee yield

The top three high yielding accession at Awada were 1377, 974, and 971 with a mean yield of 24.15, 22.83, and 21.15 Q/ha, respectively. And the lowest yield was recorded from the local landrace L-2 sampled from farmer plot (Table 14), which could partly indicate the variations associated with yield performance of coffee genotypes and the role of management practices to express the genetic potential. The coffee accessions performed differently at the three locations, possibly due to the fact that *C. arabica* coffee varieties has specific location adaptation. The other authors (Mesfin and Bayetta, 1987; Behailu et al., 2008) reported similar results.

At Korke, very high significant variation was noticed among coffee accessions for yield performance (Appendix 2). The highest average clean coffee yields of 1.9, 1.55 and 1.27 Q/ha from 75227, 85294, and 1377, respectively. This was as opposed to the lowest yield level from 85257 and 85238 (Table 14). At Konga, very high significant variation ($P \leq 0.05$) was found among coffee accessions. The highest yield was recorded from 85237, 1377, and 85257 with a mean clean coffee of 2.38, 2.17, and 2.08 Q/ha clean coffee, respectively. On the contrary, the lowest yield was recorded from coffee accession 744 with an average clean coffee of 0.47 Q/ha (Table 14).

Table 14. Mean clean coffee yield (Q ha^{-1}) of genotypes at the three study research sites

Coffee genotype	Awada	Korke	Konga
85238	18.22^{defg}	0.43^{e}	1.21^{ef}
9718	19.47^{cde}	0.64^{e}	0.89^{f}
85237	20.21^{cd}	0.57^{e}	2.38^{a}
974	22.83^{ab}	1.01^{d}	2.00^{bc}
1377	24.15^{a}	1.27^{c}	2.17^{ab}
9744	18.65^{def}	0.95^{d}	1.78^{cd}
979	20.36^{cd}	0.56^{e}	1.10^{f}
9722	16.93^{hgf}	0.60^{e}	2.34^{a}
85294	17.51^{efgh}	1.55^{b}	0.58^{g}
85259	16.12^{hg}	1.15^{cd}	1.46^{de}
85257	19.28^{cde}	0.43^{e}	2.08^{abc}
971	21.18^{bc}	1.05^{cd}	1.47^{de}
744	16.42^{hgf}	0.58^{e}	0.47^{g}
75227	15.67^{h}	1.90^{a}	1.44^{e}
L1	5.00^{i}		
L2	4.50^{i}		
L3	5.54		
LSD (P = 0.05)	2.34	0.23	0.33
CV (%)	15.09	27.33	22.99

Mean values showed by the same letter(s) within a column are not significantly different from each other at 0.05.

4.14 Effect of soil properties on coffee quality

Coffee quality can be affected by climatic and soil factors. In this study, nitrogen and phosphorous negatively correlated with coffee quality. In addition, calcium negatively coo related with the quality of coffee. Soil pH was noted to indirectly associate with the character and acidity of coffee. In addition, total quality, body and shape were directly correlated with soil pH. Except, pH, Mg and Ca, the other soil properties were negatively correlated with total

coffee quality. Above all, soil nitrogen content inversely associated with most coffee attributes (Table 16). The findings are quite in line with that of Yadessa et al. (2008) and Wintegens (2004). The effect of climatic elements, environmental/site factors including micronutrients, fertility and moisture gradients remain to be studied with the view to develop site-specific recommendations for each locality.

Table 15. The relationship between some soil properties and cup quality analysis

	Quality attribute				
Variables	TQ	CH	AC	BD	Shape
pH	0.57	-0.88	-0.27	0.90	0.62
N	-0.69	0.28	-1.00	-0.24	-0.65
P	-0.04	-0.43	-0.79	0.46	0.03
OM	-0.40	0.78	0.45	-0.80	-0.46
CEC	-1.00	0.85	-0.70	-0.83	-0.99
Ca	-0.34	-0.13	-0.94	0.17	-0.28
Mg	0.98	-0.78	0.78	0.76	0.97
K	0.92	-0.63	0.89	0.60	0.89

* and ** indicates significance at 5% and 1% level of significance at n-2 degree of freedom.

5. Summary and conclusion

The findings indicate variability among the coffee genotypes for green bean characteristics and cup quality. Accordingly, from all coffee landraces evaluated, accession 9744, 9718, 1377 and local coffee L-3 were found to be the best at Awada. At Korke, 9718, 979, and 85294 were identified to be superior. Accession 9744, 9718, and 9728 for the Yirgacheffe type had desirable character, green bean physical and cup quality as compared with the varieties. Hence, these genotypes can be used for future breeding as gene source for desirable quality traits in the Sidama and Yirgacheffe coffee quality improvements. The genotypes are location specific in terms of most quality attributes, suggesting the need to conserve and use at multiple sites within each area of origin in the Sidama and Gedeo zones.

There were also statistically significant ($P \leq 0.05$) variations in coffee quality due to the processing treatments. Hence, based on the interest of consumers and specialty market can be used in selecting the processing method. However, the wet processed coffees showed superior over all quality as compared with the methods. Thus, the selection of coffee accession and landraces can made on both statistically significant character, physical and cup quality attributes, which had a significant effect on the total quality. The effects of some soil properties were also evident on coffee quality, demonstrating the importance to consider soils for the sustainable production of high quality coffees.

The interaction effect arising from location and genotype as well genotype by processing practice were found to significant for most quality traits, demonstrating the need to consider

environmental and plant factors as well as . As a whole, it can be concluded that coffee genotypes were location specific for quality attributes. The results show that the wet and dry processing methods resulted in higher acidity and body, respectively. Therefore, coffee quality can be best improved through washing, as the results followed the order of wet > semi-washed > sun dried at all locations. However, from the present findings, it is possible to suggest the followings as high priority research areas.

- Cost benefit analysis of the various processing methods at each locality,
- Multivariate analysis of environmental factors and quality attributes under the diverse coffee production systems in the region,
- The present treatments and the other post-harvest handling and processing methods (farmers practice, demucilager, etc) should studied,
- Development of additional improved coffee varieties from the local landraces,
- Analyses of other biochemical constitutes of coffee quality,
- Development of cost-effective and environmentally friendly post-harvesting and processing methods at each area.

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7. Appendices

Appendix 1: ANOVA (mean squares) for coffee quality parameters due to processing method and coffee genotypes of Sidama coffee

a) Awada Research Sub-center.

Source of variation	Genotype (G)	Processing (PR)	G*PR	Error
DF	16	2	32	100
Shape	20.35***	111.53***	6.80***	0.947
Color	8.39***	96.57***	3.45***	0.96
Total Quality	139.62***	187.53***	15.92***	2.78
Acidity	10.64***	25.19***	2.54***	2.18
Body	9.63**	32.01***	1.74*	2.09
Character	19.78***	11.50***	6.33***	1.22
Roast volume	402.17***	6.58**	1.86*	98.23
Roast weight	85.23***	90.16***	3***	8.34
Screen	65.71***	1.36^{NS}	2.46***	5.75
Bean weight	3.7***	18.58*	2.46*	2.46

b) Korke site

Variable	Genotype (G)	Processing (PR)	G*PR	Error
DF	13	2	26	82
Shape	14.74***	44.60***	1.60NS	1.1
Color	2.62***	4.27**	0.63^{NS}	0.83
Acidity	12.12***	60.16***	4.71^{NS}	3.37
Body	12.61***	76.71***	2.69^{NS}	1.99
Character	12.99***	0.35^{NS}	9.70***	2.84
Roast volume	380.06***	412.82*	117.51^{NS}	95.01
Roast weight	57.12***	49.38*	12.80^{NS}	14.04
Screen	67.50***	25.62*	6.81^{NS}	5.86
Bean weight	16.37***	18.38***	2.65*	1.35
Total quality	159.10***	281.34***	25.41***	5.6
Yield	1.62***	0.0001^{NS}	0.02NS	0.25

*, **, *** indicates significance, highly significant, very highly significant at 0.01, 001, and 0.001, respectively. NS = Not significant.

Appendix 2: Means squares for coffee quality parameters due to processing method and coffee genotypes of Yirgacheffe coffee at Konga.

Variable	Processing (PR)	Genotype(G)	PR*G	Error
DF	2	13	26	82
Shape	62.66***	16.91***	4.52**	1.97
Color	38.49***	5.34***	1.75 NS	1.16
Acidity	25.88***	9.67***	2.84 NS	2.14
Body	41.88***	6.65 NS	2.15 NS	4.34
Character	80.89***	16.13***	5.28***	1.00
Roast volume	513.16**	252.49**	83.24 NS	97.47
Roast Weight	99.20***	38.55***	11.38 NS	8.84
Screen	238.93*	48.02***	19.15***	6.09
Bean weight	0.84 NS	10.04***	1.86 NS	1.52
Total quality	370.07***	92.19***	17.67***	2.19

*, **, *** indicates significance, highly significant, very highly significant at 0.01, 001, and 0.001, respectively. NS = Not significant.

Appendix 3. ANOVA for raw and cup quality of coffee genotypes at the study areas

Variable	Rep	Processing	Genotype (G)	LO*G
Df	2	2	13	26
Shape & make	3.25	132.55***	45.98***	19.75***
Colour	1.50	72.02***	8.54***	5.63***
Bean size	13.54	68.40***	200.39***	80.93***
Bean weight	3.38	0.50NS	26.54***	23.48***
Roast volume	216.66	14.35NS	349.70***	504.62***
Roast weight	17.42	220.68***	138.41***	54.47***
Character	3.50	22.98**	33.30***	16.20***
Total quality	4.88	1130.92***	365.70***	118.99***
Acidity	4.62	173.15***	18.59***	8.64***
Body	4.38	137.59***	18.05***	8.37***

Appendix 4.The correlation coefficient effect of processing method on the quality of Sidama coffee (Awada)

Quality attribute	Shape	Color	Acidity	Body	Character	Roast volume	Roast weight	Screen	Bean weight	Total quality
Shape										
Color	0.77***									
Acidity	0.56***	0.58***								
Body	0.23**	0.23**	0.52***							
Character	0.46***	0.30***	0.60***	0.57***						
Roast volume	-0.17	0.10	0.29***	0.44***	0.31***					
Roast weight	0.39***	0.45***	0.38***	-0.07	-0.00	-0.10				
Screen	0.52***	0.24**	0.35***	0.41***	0.49***	0.02	0.19*			
Bean weight	0.49***	0.37***	0.44***	0.4***	0.37***	-0.03	0.29***	0.64***		
Total quality	0.77***	0.68***	0.75***	0.47***	0.64***	-0.02	0.20*	0.38***	0.41***	

*, **, *** indicates the correlation value is significant, highly significant and very highly significant, respectively..

Appendix 5. Correlation values between coffee quality attributes of Sidama coffee under different processing methods

Quality attribute	Shape	Color	Acidity	Body	Character	Roast volume	Roast weight	Screen	Bean weight	Total quality
Shape										
Color	0.52***									
Acidity	0.28**	0.14								
Body	0.35***	0.39***	0.20*							
Character	-0.01	0.26**	0.41***	0.52***						
Roast volume	0.38***	0.31***	0.34***	0.38***	0.20***					
Roast weight	0.12	0.11	0.40***	0.20*	0.23**	0.36***				
Screen	0.18*	-0.08	0.30***	0.03	0.01	0.34***				
Bean weight	0.41***	0.15	0.20*	0.31***	0.01	0.40***	0.26**	0.46***		
Total quality	0.55***	0.53***	0.50***	0.48***	0.48***	0.23**	0.06	-0.14	0.05	

*, **, *** indicates the correlation is significant, highly significant and very highly significant according to their respective order.

Appendix 6: The correlation coefficient effect of processing method on the quality of Yirgacheffe coffee

Quality attribute	Shape	Color	Acidity	Body	Character	Roast volume	Roast weight	Screen	Bean weight	Total quality
Shape	-									
Color	0.84***									
Acidity	0.35***	0.53***								
Body	0.12	0.22*	0.53***							
Character	0.09	0.06	0.46***	0.62***						
Roast volume	0.45***	0.59***	0.46***	0.28***	1**					
Roast weight	0.08	0.24**	0.35***	0.43***	0.07	0.46***				
Screen	0.22*	0.27**	0.15	0.19***	0.34*	0.28**	0.22*			
Bean weight	0.52***	0.58***	0.49***	0.55***	0.32***	0.58***	0.48***	0.50***		
Total quality	0.59***	0.62***	0.53***	0.37***	0.45***	0.44***	-0.07	0.18*	0.54***	-

8. Biographical sketch

The autor was born on September 11 1975 at Yirgalem. He started education at Meskerem 2 (Aderash) primary school and transferred to Mekane Yesus Junior Secondary School and completed his primary and junior secondary school in 1980. In 1981 he joined Yirgalem C.S.S.School education and took ESLCE in 1984. He joined Ambo college of agriculture and graduated in 1984. In 2002 joined Haremaya University and graduated in 2006 with a B.Sc. degree in agriculture (Plant sciences).

In 1986, he was employed in Ministry of Education and worked as a teacher till 1990. He then transferred to the Ministry of Agriculture and Rural Development and worked in various departments and sections as agronomist, quality control expert, Crop and fertilizer trial expert, team leader and other related fields.He then transferred to Addis Abeba to be a coffee liqurer .After training and certification as coffee liquorer, working as coffee liquorer in Ethiopian Coffee Quality Inspection and Grading Center. He joined the school of graduate studies at Hawassa University on September 2007 to pursue his studies for master of Science in plant sciences, specialization: Horticulture.