INFLUENCE OF PROCESSING METHODS ON THE QUALITY PERFORMANCE OF ARABICA COFFEE HYBRIDS AND PARENTAL LINES IN JIMMA ZONE

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INFLUENCE OF PROCESSING METHODS ON THE QUALITY PERFORMANCE OF ARABICA COFFEE HYBRIDS AND PARENTAL LINES IN JIMMA ZONE

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In Partial Fulfillment of the Requirements of Degree of Master of Science in Horticulture (Coffee, Tea and Spices)

By

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As *Thesis* research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by **Seble Eshetu**, entitled as **'Influence of Processing Methods on the Quality Performance of Arabica Coffee Hybrids and Parental Lines in Jimma Zone'**. I recommend that it be submitted as fulfilling the *Thesis* requirement.

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DEDICATION

I dedicate this thesis to my father Ato Eshetu Genet, my mother W/ro Adanech Tefera and my brother Fikru Eshetu.

STATEMENT OF THE AUTHOR

I declare that this thesis is my work and that all sources of materials used for this thesis have been acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. Degree at Jimma University College of Agriculture and Veterinary Medicine and is deposited at the University Library. I declare that this thesis is not submitted to any other institutions anywhere for award of any academic degree, diploma, or certificate.

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BIOGRAPHYCAL SKETCH

Seble Eshetu was born on June 29, 1986 in Addis Ababa town. She attended her elementary and junior educations at Addis Hiwot Elementary and Yemanebirhan Junior Secondary School, respectively from 1993 to 1999. She attended her high school and preparatory class at Ayer Tenna High School and Higher 23 Senior Secondary School, respectively from 2000 to 2003. She then joined the Jimma University, College of Agriculture and Veterinary Medicine in 2004 and graduated with B.Sc., degree in Horticulture in June 2006. After graduation, she has been employed by the Ministry of Education and stationed at Jimma University Ambo College of Agriculture (now Ambo University) in 2007. She rejoined the School of Graduate Studies at the Jimma University College of Agriculture and Veterinary Medicine in 2009 to pursue her M.Sc. degrees in Horticulture (Coffee, Tea and Spices).

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LIST OF ABBREVIATIONS

CBD	Coffee Berry Disease
CRF	Coffee Research Foundation
CRI	Coffee Research Institute
ECX	Ethiopian Commodity Exchange
EEA	Ethiopian Economic Association
FAO	Food and Agriculture Organization of the United Nations
IAR	Institute of Agricultural Research
ICO	International Coffee Organization
ISO	International Standard Organization
ITC	International Trade Center
JARC	Jimma Agricultural Research Center
JZARDO	Jimma Zone Agricultural and Rural Development Office
MC	Moisture Content
OTA	Ochratoxin A
SAS	Statistical Analysis Software

INFLUENCE OF PROCESSING METHODS ON THE QUALITY PERFORMANCE OF ARABICA COFFEE HYBRIDS AND PARENTAL LINES IN JIMMA ZONE

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ABSTRACT

*Despite the presence of wide genetic and ecological variations for improving the desirable traits (yield, quality, disease and pest resistances and drought tolerance) in Ethiopia, the national average coffee yield remains low as compared to other coffee producing countries. Since the inception of a coffee breeding program in Ethiopia, many varieties including the three coffee hybrids have been released for medium altitude areas of southwestern Ethiopia. The quality of the hybrid varieties was acceptable under research stations, nevertheless little is known under on-farm conditions. Moreover, the previous research has given little attention to processing method and environmental effects on bean quality as well as varietal variations in bean quality. The objective of this study was, therefore, to determine the effects of processing methods on the bean physical and organoleptic quality attributes of the released varieties of arabica coffee hybrids, parental lines and local coffees growing under the conditions of Jimma area. For this, selectively harvested ripe cherries from 7 coffee varieties (3 hybrids: Ababuna, Gawe and Melko-CH2, 3 parental lines: 741, 74110 and Dessu, and a local) grown in Seka Chekorsa and Manna Weredas were processed in Wet and Dry methods, and evaluated for bean physical and sensorial quality characters using a factorial arrangement in CRD with 3 replicates. The results depicted that there were no significant variations between locations and the sensorial quality parameters, except body and aromatic quality, did not differ due to the main and interaction effects. However, body had significant variations (P< 0.05) among varieties and between processing methods, with the highest values for Ababuna and wet processing, respectively. Although the result showed statistically significant variation (P<0.01), the mean values for color in both processing methods indicated nearly grayish color. Above screen size14" (ABS), 100 bean weight (HBW), and shape and make (P<0.01) and aromatic quality (p<0.05) were significantly affected by the three-way interaction of location, variety and processing method. Seka * Gawe * Dry, Manna * 74110 * Wet, Manna * Dessu * Wet and Seka * Melko-CH2 * Wet had very good shape and make with uniform appearance. Seka * Gawe * Dry and Manna * 74110 * Wet also showed the highest HBW and ABS, respectively, and more 91% beans of all varieties had bean size greater than screen size14". Manna *Ababuna * Dry and Seka *741 * Dry showed the strong aromatic quality; but the rest combinations had medium. There was positive and significant correlation between most of the cup quality attributes except astringency. But, there was no significant and positive correlation between cup and physical quality attributes, showing the difficulty to use bean physical attributes for cup quality improvement. From this finding, it can be concluded that all varieties exhibited almost similar and fairly acceptable quality performance under research and farmers' field conditions and two processing methods in the tested Weredas of Jimma zone. However, further studies should be progressed on all physical, cup and biochemical bean quality attributes of more varieties over multi-locations and seasons.*

1. INTRODUCTION

Coffee belongs to the family *Rubiaceae* and the genus *Coffea***.** From the three economically important species, *Coffea arabica*, *Coffea canephora* and *Coffea liberica*, only the former two are consumed widely as a non-alcoholic stimulant beverage in the world. Arabica coffee (*Coffea arabica* L.) is by far the most important economic species in the world coffee market (Bayetta, 2001). It is the only self-fertile with less than 10 percent cross-pollination, tetraploid species (2n = 4x = 44), while others are diploids (2n = 22) and self-incompatible (Anthony *et al.*, 2001).

Ethiopia is the center of origin of *Coffea arabica* where it can grow in altitudes, ranging from 1300 to 2000masl (Wintgens, 2004). Arabica coffee can be best produced with annual rainfall amount ranging from 1500 to 2500mm with an ideal minimum and maximum air temperatures of 15 and 25^{o}C, respectively. This prevails in most of coffee growing areas of the country. But, for extremes and some cases it grows up to 550masl (like Bebeka) and in areas where annual rainfall ranges from 1000-2000mm (Bayetta, 2001).

The economic value of coffee is determined both by the yield potential, the size and shape of raw beans, quality of roast bean and its liquor. Yield determines the quantity of various bean sizes (commercially referred to as grades) that become available for sale at any time (Agwanda *et al.*, 2003). Arabica coffee is the major source of foreign currency for Ethiopia and contributes more than 35% of the total export earnings (FAO, 2008). Thus, it is a cornerstone in the export economy of the country and it supports directly or indirectly the livelihood of some 15 million people (EEA, 2001). Besides an important export crop, coffee plays a vital role both in the cultural and the socioeconomic life of the country. Coffee the defining feature of the national culture and identity, 44% of the production consumed domestically (Mayne *et al.*, 2002).

Since coffee is one of the leading marketable commodities next to oil, qualified professionals are seriously investigating the quality of coffees. The specialty markets of coffee are paying the premium price for the specialty preparation of coffee that keeps its original types. In this regard, quality is a must that one can observe as a raw and cup quality. Indeed, assessment of organoleptic quality is an extremely demanding exercise (Leroy *et al.*, 2006). Production and supply of coffee with excellent quality seems more crucial than ever before for coffee exporting countries. Consequently, some countries consider assessment of coffee quality as important as disease resistance and productivity in their coffee variety development program (ITC, 2002).

Though quality is an inherent factor, environmental and genetic factors play the major role in determining the expression of coffee physical and organoleptic quality attributes (Leory *et al.*, 2006). In Ethiopia, there are numerous factors that determine coffee quality. The major ones are genotype, climate and soil conditions of the growing area of coffee, agricultural practices, time and methods of harvesting, postharvest processing techniques, packing, storage condition, and transportation (Dessie, 2008). Of these various factors, pre and postharvest processing techniques are believed to have large contribution for the decline of coffee quality (Dessie, 2008).

The coffee bean is a seed of a small fruit known as cherry, and processing in coffee is the various steps and methodologies used to separate the beans from the fruits and drying of the beans and/or cherries. Wet and dry methods are the two major processing techniques in coffee (Dessie, 2008). In the wet method, the pulps of fresh cherries are pulped and the parchment coffee beans are dried after fermenting and washing of the mucilage. Whereas in dry processing, fresh cherries are dried with its pulp and the beans are separated from dried pulp (husk). Wet-processed or washed coffees tend to be cleaner and brighter in appearance, and more acidic in taste than dry-processed, natural or unwashed coffees. On the other hand, dry-processed coffees are generally more idiosyncratic in flavor and heavier in body than wet-processed coffees (David, 2008).

In Ethiopia, there are favourable agroecologies for coffee production, enormous variability of coffee types for quality and other traits improvement and long history of coffee production. However, the national average coffee yield is low, 6q/ha (Bayetta, 2001; Anwar, 2010), which is mainly contributed by lack of improved varieties (Bayetta, 2001; Kassahun and Getnet, 2008). To overcome this constraint of improved varieties and thereby to improve the productivity, coffee research in Ethiopia has been conducted for four decades with main target to develop CBD resistant, high yielding and wide adapting varieties for major coffee growing areas of the country (Getu, 2009). As result several disease resistant and high yielding coffee varieties including three hybrid varieties have been released so far (Arega *et al.*, 2008). The three hybrid varieties namely; Ababuna, Melko-CH2 and Gawe, gave more yield than the best standard check variety (Dessu) both on research station and farmers' field, and their quality on research station is acceptable (Behailu *et al.*, 2008a), but their quality on farm condition is not yet tested. In addition, the previous research generally gave less attention to investigate the variability of coffee types for various quality traits and the influence of processing methods and environment on the quality of different varieties of coffee. However, some recent studies tried to focus on postharvest handling and quality aspects of coffee. E.g. Anwar (2010) assessed coffee quality and its related problems in Jimma Zone and he observed that the recommended preparing method promotes the typical quality profile to the final cup quality to meet consumers' choice. Getu (2009) and Yigzaw (2005) worked on organoleptic quality traits' variation with respect to genotype by environment interaction, and they reported that most of genotypes showed unstable performance for organoleptic quality attributes.

Taking the existing limitations in to account, this study was, therefore, designed to generate information on the quality performance of coffee varieties grown on farmers' field and research stations in Jimma Zone and the effect of processing methods on coffee quality with the following objective:

- To determine the effects of processing methods on the bean physical and organoleptic quality attributes of the released arabica coffee hybrids, parental lines and local coffees growing under the conditions of Jimma Zone.

2. LITERATURE REVIEW

2.1. Botany of Coffee (*Coffea arabica* L.)

Coffea is the major genus of the family Rubiaceae, which includes over 500 genera and 6000 species (ITC, 2002), mostly trees and shrubs, mainly found in the lower regions of the tropical rainforest (Graff, 1986). The genus *Coffea* itself comprises of 105 species, but only two of them are currently of real economic importance (Wrigley, 1988).

Arabica coffee is an evergreen shrub of variable size. The tree grows up 8-10m high and its branches are long, flexible and thin. Branches are semi-erect when young and spreading when old (Coste, 1992). The architecture of the coffee is characteristic of a tree growing in tropical forests: a vertical (orthotropic) stem, with horizontal (plagiotropic) branches arising in pairs opposite to each other. The growth is by a typical form of monopodial branching where the branches (primaries) remain subsidiary to the main stem, which continues to grow indefinitely by extension of the apical bud (Wrigley, 1988).

All botanists, who have explored the forest in the south western highlands of Ethiopia, agreed that Ethiopia is the center of diversity of *C. arabica* L. (Wilson and Clifford, 1985). It is known for the longest time and it is the most wide spread species throughout the world. It is evergreen, often multi stemmed shrub. The ovary develops into a globular or oval drupe, normally containing two seeds. It has a length of 14-18mm and a diameter of 10-15mm. It is usually called a cherry or a berry (Graff, 1986).

The coffee plant takes approximately three years to develop from seed germination to first flowering and fruit production. A well managed coffee tree can be productive for up to 80 years or more, but the economic life span of a coffee plantation is rarely more than 30 years (Wintgens, 2004). 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 integument, known as the silver skin (Graaff, 1986).

Arabica coffee has numerous botanical varieties, mutant and cultivars, which reflect the influence of environment (Wrigley, 1988). Among the many varieties, the most important ones are *C. arabica* L. var. typica and *C. arabica* L. 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).

2.2. 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 expressing quality. In addition, what it constitutes. 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. Nowadays, this definition varies along the production to consumer chain (Leroy *et al.,* 2006):

- 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 characteristic 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)

2.2.1. Physical quality

According to the International Standardization Organization (ISO, 2004), a standard for green coffee quality requires several pieces of information, like the geographical and botanic origins of the coffee, the moisture content, and the bean size. These ISO standards define methods of measurement for several of these qualities: moisture content, bean size, and preparation of a sample to perform cup tasting. Similarly, Endale (2008) reported that Grading and classification is usually based on altitude and/or region, botanical variety, preparation (wet or dry process), bean size (screen size), shape and make, color, number of defects, bean weight, and cup quality (flavor, characteristics, cleanliness). ISO (2004) has established a standard 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, visual appearance such as black beans, and taste of the cup after proper roasting and brewing.

Bean size, defined as grade from a commercial point of view, is an important factor since price is related to the coffee grade (small beans of the same variety can bring lower prices) (Leroy *et al*., 2006). 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 (Yigzaw, 2005). When uneven sized beans are roasted, the smallest lead to burn and the largest tend to be under roasted, affecting the visual appearance of the beans and more importantly, the cup quality (Leroy *et al*., 2006).

The size and shape of the beans differ depending upon the variety, environmental conditions and management practices. On average, beans are 10mm long, 6-7mm wide, 3-4mm thick and weigh between 0.15 and 0.20g. Bean color can be yellowish-grey to slate-grey, bluish or grey-green, depending upon the variety, method of preparation and storage condition (Coste, 1992). Bean shape may be sub-globular, ovoid, oblong, linear-oblong, either rounded at both ends or pointed at one end and rounded at the other (Wrigley, 1988).

Moisture is an important attribute and indicator of quality. If the beans are too wet (above 12.5% moisture) they will develop mould easily during storage. On the other hand, if the beans are too dry (below 8% moisture) they loose flavor (ITC, 2002). According to (CRI, 2006) coffee must be dried from approximately 60% to 11-12% moisture content. In addition, the moisture content of the beans influences the way coffee roast and the extent of weight lose during roasting. Green coffee with low moisture content tends to roast faster than those with high moisture content (ITC, 2002).

2.2.2. Organoleptic quality

Quality of liquor determines the desirability of coffee for consumption purposes, and hence, acts as yardstick for price determination. Its assessment is done organoleptically by panel of experienced coffee tasters as described by (Walyaro, 1983). 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. In addition, organoleptic characteristics must be stable, especially for the roaster and the consumer. Organoleptic quality measurement relies on overall sensory evaluation (Leroy *et al*., 2006). According to Lingle (1986), coffee cupping consists of different steps to evaluate the coffee’s fragrance, aroma, after taste and body. In Kenya and Colombia for example, liquor quality is determined on the basis of the level of acidity, body, and flavor of the brew. These three traits are known to determine, to a large extent, the liquor quality of coffee (Devonshire, 1956 as cited by Agwanda *et al*., 2003).

Acidity indicates the bitter or acidic balance and the presence of a sweet caramelic after taste. The acid content in a brew is also greatly dependent upon the degree of roast, type of roaster, and brewing method. Uneven roast results in poor quality liquor. Dark roast enhance the body while light roast emphasizes acidity (ITC, 2002). High acidity gives better quality and more intense aroma to the beverage (Clifford and Willson, 1985). The pH of a coffee has been found to correlate with the perceived acidity of a coffee. A pH of 4.9 to 5.2 is the preferred range for a good cup of coffee. Body is synonymous with mouth feel or linked with density and viscosity of the brew (Petracco, 2000).

Flavor obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee (more than 800 in the roasted coffee) (Belitz *et al.*, 2004). According to Yigzaw (2005) good cup quality attributes are positively and significantly correlated among themselves. Flavor had relatively high correlation with all other cup quality traits. Thus, selection for all rounded cup quality improvement can be achieved using flavor rating alone. Green bean physical characters are not good indicators for cup quality improvement (Yigzaw, 2005). According to Agwanda *et al*. (2003) quality evaluations based on multi-site trials could be used to identify environments that best reveal differences in genetic potentials amongst varieties and hence useful as selection and/or test sites. This could improve the efficiency with which selection for superior quality could be attained.

The aroma of a coffee is responsible for all flavor attributes other than the mouth feel, and sweet, salt, bitter, and sour taste attributes that are perceived by the tongue. Therefore, it might be said that the aroma is the most important attribute to specialty coffee (Viani, 2003). Aroma is perceived by two different mechanisms. It can either be sensed nasally via smelling the coffee through the nose or retro nasally. Retro nasal perception occurs when the coffee is either presents in the mouth or has been swallowed and aromatic volatile compounds drift upward into the nasal passage. Yet, the perception of aroma is dependent upon both the concentration of the compound and its odor threshold. It is probable that a relatively small group of compounds that share both a high concentration and a low odor threshold make up the fragrance we know as coffee aroma (Bertrand *et al.*, 2005).

Walyaro (1983) reported the presence of large inherent differences among genotypes for bean and cup quality attributes. Similarly, Vander Vossen (1985) observed variation for cup quality characters among varieties and crosses of arabica coffee. Selvakumar and Sreenivasan (1989) observed coffee quality variation ranging from good to excellent among 54 arabica coffee accessions collected from Keffa province of Ethiopia. Roche (1995) assessed the association of cup quality and green bean physical characters using 15 *C. arabica* L. cultivars and reported that bean size was not a good indicator of cup quality when comparing cultivars from a single production area. Similarly, Agwanda *et al*. (2003) reported that bean quality traits were not useful for enhancement of genetic gains on cup quality and vice-versa. Muschler (2001) reported that proper ripening and slower filling had remarkable impact on cup quality.

2.2.3. Health quality

For consumers, one of the most important components of quality for alimentary goods is food safety. Coffee contains a lot of molecules that can have an effect on health and alertness. Some of them are naturally present in coffee beans or derived from biochemical reactions occurring during roasting, whereas others like Ochratoxine A (OTA) and residues of pesticides are external compounds independent of the chemical composition of coffee beans (Leory *et al*., 2006).

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 (Leory *et al*., 2006 and Eshetu and Girma, 2008).

Despite its positive effect on alertness, caffeine also has some possible implication on health like hyper cholesterol and cancers. Coffee also contains chlorogenic acids, melanoidins, and other unknown substances which are identified as strong antioxidants (Leory *et al*., 2006).

2.3. Factors Affecting Coffee Quality

Coffee quality is a complex characteristic which depends on a series of factors such as genetic factors, environmental conditions, agronomic practices, processing systems, storage conditions (Moreno *et al.,* 1995).

2.3.1. Genetic factors

Coffee quality, in the present context of overproduction worldwide, has to be considered as a main selection criterion for coffee improvement. In addition, the genetic factors also known as intrinsic factors are involved in the control of coffee quality. The great variation within and between coffee species is underlined, mainly for biochemical compounds related to quality (caffeine, sugars, chlorogenic acids, lipids, etc) (Leory *et al.*, 2006).

Ethiopia is the home of coffee (*Coffea arabica* L.) and there exists extremely diverse genetic reserves in the montane rainforests of southwest of the country (ICO, 2004). Bayetta (2001) reported that morphological variation is more important than variation in geographical origin as an indicator of genetic diversity in Ethiopian coffee. Seyoum *et al.* (2004) also indicated the presence of trait diversity among eighty-one Ethiopian coffee accessions that can be exploited in the genetic improvement of the crop. 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 (Mekonen, 2009).

Since the 1980s, several researchers have proposed the creation of hybrid varieties to help in increasing genetic diversity, notably by crossing wild Ethiopian origins with introgressed or non introgressed varieties and to exploit heterosis between genetic groups. Ethiopian origins provide resistance to nematodes, partial resistance to leaf rust and resistance to CBD and likely a better beverage quality (Leory *et al*., 2006). Based on organoleptic evaluation, introgressed lines of arabica were found to produce good beverage quality that was similar to the non introgressed standard (Moreno *et al., 1995;* Leory *et al*., 2006).

Under Central American conditions, no clear differences were found for bean chemical contents and cup quality in sensory evaluations comparing F1 hybrids with traditional cultivars (‘Bourbon’) under various edapho-climatic conditions and at different elevations (Leory *et al*., 2006). F1 hybrids appeared in turn to be inferior, similar, or superior to traditional cultivars for certain attributes, such as acidity, or aroma. For caffeine, as for trigonelline, the hybrids did not differ from the traditional varieties. The hybrids showed a tendency to be slightly richer in chlorogenic acids than the traditional varieties (Leory *et al*., 2006). The performance of F1 hybrid plants derived from crosses between traditional varieties of *Coffea arabica* of Latin America with a “wild” collection of Sudan–Ethiopian origin were studied for yield, fertility and bean weight by comparing them to those of the best parental ‘control’ lines in each trial. Selection in the hybrid populations using the three selected traits led to significant genetic gain for yield and dry weight of 100 beans, and insignificant gain for fertility (FF). The yield performance of these hybrids calls for further selection effort for improving beverage quality (Bertrand *et al*., 2005). An arabica coffee cultivar (cv Ruiru 11), which was released by Coffee Research Foundation (CRF) of Kenya in 1985, is resistance to disease and suitable for all coffee growing areas with high yield, fine cup quality and compact growth (Kathurima *et al*., 2010).

Comparisons of different varieties based on organoleptic evaluation and several scientific procedures indicate that similarities and differences are attributable to genetic traits. Benoit *et al*. (2006) reported the effects of variety and elevation on cup quality. Flavor is a very complex trait that is affected by many genetic components and non-genetic factors and also, physical quality like shape and make is affected by the type of the variety (Endale, 2008) and size difference of coffee beans were influenced by botanical variety (Yigzaw, 2005 and Mekonen, 2009).

2.3.2. Non genetic factors

In addition to the genetic factors, the most important factors that dictate coffee quality are soil and climatic factors, cultural practices, harvesting, postharvest handling, processing, storage and roasting.

2.3.2.1. Pedo-climate

Climate, altitude and shade play an important role through temperature, availability of light and water during the ripening period. Rainfall and sunshine distributions 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 (Leory *et al.*, 2006). Volcanic soils often produce a potent acidity and a good body such soils can lead to a more balanced cup (Bertrand *et al.*, 2005). Soil consists of both mineral particles and organic matter, and the nature and amount of these components in the soil influences its characteristics (Castrignano *et al.*, 2000).

Altitude has a powerful effect on the flavor profile of coffee. Coffee plants at lower elevations are subjected to greater heat, less ventilation, and less diurnal temperature contrast. These phenomena leads to coffee cherries with their beans inside ripen more quickly and develop smooth, duller, sometimes earthier, flavor tones than coffees grown at higher elevations (Howell, 2009). According to Guyot (2001) altitude is related with quality. The higher altitude grown coffees typically display the best overall flavor characteristics; this is mostly a function of how slowly a coffee is grown. High altitude favor better aroma and flavor formation. Environment, genetic and the interaction of both factors influence “typicity” of coffee cup quality. In addition, physical quality like shape and make and size of the bean is affected by the environment where the coffee is growing (Yigzaw, 2005; Endale, 2008 and Mekonen, 2009). Minimizing available sunlight via shade trees for coffees grown on low altitude can produce the same physical and organoleptic effect as growing a coffee at a slightly higher altitude. This being the case in point, shade is typically somewhat difficult to monitor and high altitudes will often result in a more uniform quality (Guyot, 2001).

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” (Sivetz and Desrosier,1979). There is 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 (Wintgens, 2004).

According to Howell (2009) temperature is the most important element, which affects coffee bean quality. The higher the temperature, the higher is 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 as10^{o}C. Coffee needs to be maintained at low temperature to reduce its metabolism and respiration.

2.3.2.2. Cultural practices

According to Cannel (1971) as cited by Agwanda *et al*. (2003) the majority of reported works on the improvement of coffee quality primarily concerns agronomical and processing practices that directly impose on coffee quality. It is widely agreed that traditional hand pricking, as opposed to mechanical harvest, produces the best quality green coffee by decreasing the percentage of defects in coffee batches. Then, depending on the post harvest process, strong consequences on coffee quality can be observed (Leory *et al*., 2006).

Among others, coffee plant nutrition is reported to be influential not only on yield but also the final cup quality of the liquor. Soil nutrients may be inherited from the parent materials or added through the use of external inputs (organic and inorganic fertilizer) (Castrignano *et al.,* 2000). In South America, coffee grown with heavy application of nitrogen fertilizer had poorer and lighter quality than that from unfertilized fields (Wellman, 1961 as cited by Yigzaw, 2005). An excess of nitrogen increase the caffeine content, resulting in a more bitter taste of the brew. The caffeine and chlorogenic acid contents of the beans are not affected by the levels of phosphorus, calcium, potassium and magnesium in the soil and there is no correlation between the phosphorus content and the physical and organoleptic quality of the bean. A lack of zinc will lead to the production of small light grey-colored beans, which will produce poor liquor. High concentration of calcium and potassium in the beans is associated with a bitter and hard taste (Wintgens, 2004).

Good growth conditions usually have a positive effect on the bean size and flavor (Wintgen, 2004). In a number of coffee growing countries, pruning is a major cultural operation which concentrates the vigor of the tree in those parts which will produce the best fruit over a number of seasons, and cuts away the other portions. Pruning also controls the position on the bushes where the crop will be produced. It leads to more cherry being produced on the primaries where the boldest beans which produce the best quality coffee are borne. Also, when the bearing wood becomes weak the bean size deteriorates (Wrigley, 1988).

2.3.2.3. Harvesting

Harvesting is an essential stage in coffee quality. In the great majority of the producer countries, coffee is hand picked. To ensure a good quality coffee, the cherries should be picked one by one; ensuring that only ripe cherries are harvested (FAO, 2009). It is widely agreed that traditional hand picking and husbandry labor, as opposed to mechanical harvest, produce the best quality green coffee by decreasing the percentage of defects in coffee batches (Mawardi *et al.,* 2005). 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 coffee 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 (Wintgens, 2004). The existence of black beans after drying (which give hard, bitter and woody beverages) is largely attributable to harvesting of green or unripe cherries because they are more difficult to dry; cherries fallen to the ground and cherries partially dried on the tree may have been rehydrated and can cause for the formation of black beans. If the cherries picked are too ripe, they give unpleasant and fruity flavors to the beverage (FAO, 2009).

2.3.2.4. Processing

Coffee processing must begin immediately after the fruit is harvested, to prevent the pulp from fermenting and deteriorating. The commercial coffee beans are prepared in one of two ways: dry and wet processing (Hicks, 2002). The processing method used on a coffee is usually the single largest contributor to the flavor profile of a coffee (CRI, 2006).

The processing of a coffee will have the most dramatic effect on the flavor. The flavor differences between a dry processed and wet-processed coffee will typically be more dramatic than regional flavor variations. If every stage of processing goes well, the regional distinctions become prominent. If any step along the processing chain is faulty, the defect produced will ambiguous the regional distinctiveness (Guyot, 2001). Recently, researchers have begun to look in to processing as an important determinant of quality. Processing experiments with samples of similar ripeness show that the processing method itself creates significant differences in the beans (Daniels, 2009). The two main processing methods have measurably different effect on the sugars and flavor precursors present, which in turn play a role in complex metabolic processes that the bean undergoes during processing and drying (Daniels, 2009).

Dry processing is the simplest and cheapest method. It produces a natural coffee (Hicks, 2002) that is heavy in body, sweet and smooth (CRI, 2006). First, the harvested berries are sorted and cleaned to separate the unripe, overripe, and damaged berries, and to remove dirt, soil, twigs, and leaves. The harvested berries are then spread out in the sun and raked regularly to avoid fermentation and to expose them evenly to the sun’s rays (Hicks, 2002).

Coffee drying is always a delicate operation which should be carried out carefully. It is the key operation in coffee processing and assumed as the major factor affecting the coffee quality (Mulato and Muhlbauer, 2003). According to 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.

Wet processing is another method of coffee preparation. It produces so called a washed coffee (Hicks, 2002) that is clean, bright and with fine acidity (CRI, 2006). During wet processing the beans are removed from the fruit called pulping and allowed to ferment to remove slippery mucilage layer, washed, and dried (Daniels, 2009). This involves huge capital outlay, plenty of water and extensive care than the dry method. The main difference between the wet and dry methods is that the wet method removes the pulp from the bean within 12-24 hrs of harvesting instead of allowing the berries to air dry (Hicks, 2002).

In the washed coffee production, final quality, among other factors is greatly dependent up on the fermentation process (Woelore, 1993). According to Brownbridge and Michael (1971) it has been confirmed that fermentation enhances the appearance of both raw and, particularly and consistently, the roast of coffees. Woelore (1993) reported different recommended fermentation time for different agro-ecologies. According to him, mucilage degradation washed at the first, second, third, and after the third day from pulping in the altitudinal range of 1200m and below, 1200-1500m, 1500-1800m and above 1800m, respectively. Post fermentation soaking for 24 hours produced better raw and roast appearances than either 8 or 16 hour soaking. Extending the soak to 48 hours in unreplicated trial did not cause any further improvement to raw, and reduced the roast quality (Behailu *et al.*, 2008b). The recent experiments on the two main processing methods with coffee cherry samples of similar ripeness showed different effects on bean sugars and flavor precursors, which in turn play a role in complex metabolic processes that the bean undergoes during processing and drying (Daniels, 2009).

2.3.2.5. 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 (Kader, 1992). During storage some changes in the quality and appearance of the green coffee can be expected (including the potential development of moulds). Storage of coffee in a producing country can be in the form of dried cherry or dry parchment coffee, or, cured green coffee. Storage conditions need not be exactly the same, since both husk and parchment provide a good protection against insects and also a barrier against moisture transfer (FAO, 2009). In storage, quality deterioration occurs due to an increase of moisture content of the bean, the spoiling of the raw appearance of the bean by color fading or tainting, or the introduction of unpleasant flavors by infestation of storage insects or infection with moulds or bacteria. Factors such as total rainfall, relative humidity, temperature with effect on water vapor content of the air, and storage duration, greatly influence storability and quality of stored coffee (Woelore, 1995).

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 (Kader, 1992). The moisture content of coffee for satisfactory storage should not be over 11%. At this level, mould growth and enzymatic activity is minimal. Besides this, due to the inherent imbalance between supply and demand in the coffee market, it is sometimes necessary to store coffee for long period of time in which the length of storage affects the quality of coffee (QSAE, 2007).

2.3.2.6. 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 during cup tasting, which is a matter of consumer preference. Uneven roast results in poor quality liquor. Dark roast enhances the body, while light roast emphasizes acidity (ITC, 2002). Roasting 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 and Prodolliet, 2004).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The samples for the study were collected from the famers' field of Koffe and Haro kebeles, Jimma Agricultural Research Center (JARC) and Agaro Agricultural Research Sub-Center (AARC) in 2009/2010. All quality analyses were conducted at JARC. Haro and AARC are located in Manna Wereda, and Koffe and JARC in Seka Chekorsa Wereda in Jimma Zone, southwestern Ethiopia. The Jimma Zone of the Oromia Regional State has seventeen weredas of which ten are suitable for the production of Limu Specialty Coffee Type, which is known in the word coffee market. Manna Wereda is located at 36^{o}43'5.49"E longitude and 7^{o}46'28.92"N latitude in the southwest of Jimma town. It is characterized by altitude ranging from 1400 to 2610masl; annual rainfall between 1312mm and 1600mm with mean minimum and maximum air temperatures of 13.1^{o}C and 24.8^{o}C, respectively. Distric nitosols and orthic acrisols are the dominant soil types in this Werada (JZARDO, 2008). On the other hand, Seka Chekorsa Wereda is located at 36^{o}29'59.64"E longitude and 7^{o}29'33.87"N latitude in the west of the Jimma town. It has mean minimum and maximum air temperatures of 11.0^{o}C and 28.4^{o}C, respectively and average annual rainfall of 1342mm. The elevation ranges from 1500 to 2800masl. Clay loam and very deep acrisols are the dominant soil types in this wereda (JZARDO, 2008).

JARC is geographically located at 7^{o}46'00"N latitude and 36^{o}47'00"E longitude at an elevation of 1753masl. The mean maximum and minimum temperature of the center are 26.2^{o}C and 11.3^{o}C, respectively. The mean annual rainfall is about 1529.5mm. The dominant soil type is Eutric Nitosols (EIAR, 2004). AARC is located at 7^{o}51'00"N latitude and 36^{o}35'30"E longitude at elevation of 1630masl. Its mean maximum and minimum air temperatures are 28^{o}C and 12.4^{o}C, respectively, and the mean annual rainfall is about 1616mm. Mollic nitisols is the major soil type (Elias, 2005). Since the distance between Koffe and JARC is only 10km and between Haro and AARC is 18km, Koffe and JARC, and Haro and AARC have similar edapho-climatic descriptions.

3.2. Experimental Materials and their Field Management

The released coffee hybrids used for the study were planted in 2006 at Koffe (Seka Chekorsa) and Haro (Manna). Three-hybrid coffee varieties viz, Ababuna, Melko-CH2 and Gawe and their respective parental lines 741, 74110 and Dessu were used for the present work. Reports (IAR, 1996; Bayetta *et al.,* 1998; Behailu *et al.,* 2008b) indicate that these coffee varieties had distinct characteristics (Table 1). A well known and recognized local coffee type from each locality was also included for the study.

The varieties, except variety 74110 that was planted in spacing of 1.8m by 1.8m, were planted in 2m by 2m row and plant spacing. All varieties were grown under 50% shade level and agronomic practices such as fertilizer and mulching were uniformly applied at each location in order to control any source of variation. Weed for all varieties at both locations was controlled by slashing and the fields were maintained clean.

Table 1. Characteristics of the coffee hybrids and their parental pure lines used for the study

Character		741	74110	Dessu*	Ababuna*	Melko-CH2*	Gawe
Origin		Gera/Jimma	Bishari/Metu	Bonga	741xDessu	7395xDessu	74110xDessu
Yield (q/ha)	On-farm	6.8	5.5	14.7	15.5	13.1	19.9
	On-station	14.4	13.4	20.0	23.8	24.0	26.06
Canopy nature		Open	Compact	Medium open	Medium open	Medium open	Medium compact
Quality	Raw quality	Fair/Good	Average/ Good	Good	Average	Average/ Good	Average/ Good
	Cup quality	Average	Good	Average/ Good	Average	Average	Average
Disease resistance		CBD resistant	CBD resistant	CBD resistant	CBD resistant	CBD resistant	CBD resistant
Release year		1978	1980	1998	1998	1998	2002
Recommendation area		Highland and midland	Highland and midland	Intermediate and lowland	Intermediate and lowland	Intermediate and lowland	Intermediate

Source: IAR (1996), Bayetta *et al*. (1998) and Behailu *et al*. (2008b)

* These varieties are resistant to CBD only for their recommended areas where CBD pressure is relatively lower

3.3. Experimental Factors and Design

Two locations representing potential and recommended coffee growing areas of the Jimma Zones for the released hybrid coffee varieties were selected purposely. The hybrids and local coffees were collected from farmers' field in Koffe and Haro whereas parental lines were collected from respective research centers (JARC and AARC) representing the profile of the two Weredas. The treatments consisted of two locations, two processing methods and 7 genotypes. Then, the treatments were arranged using factorial experiment in a Completely Randomized Design (CRD) with three replications.

Table 2. Details of the treatment combinations of the study

Location (Wereda/Kebele)	Coffee varieties and processing methods	
	Dry	Wet
Manna/Haro	741	741
	74110	74110
	Dessu	Dessu
	Ababuna	Ababuna
	Melko-CH2	Melko-CH2
	Gawe	Gawe
	Local-Manna	Local-Manna
Seka Chekorsa/Koffe	741	741
	74110	74110
	Dessu	Dessu
	Ababuna	Ababuna
	Melko-CH2	Melko-CH2
	Gawe	Gawe
	Local-Seka	Local-Seka

3.4. Experimental Procedures

Sampling Method

From both locations, a total of 504kg red fresh coffee cherries were handpicked from representative coffee trees at peak harvesting period. From these 504kg fresh cherries, a total of 84 coffee samples (3 replications x 7 varieties x 2 locations x 2 processing methods) each consisting of 6kg fresh cherries were prepared. Each sample was separately processed by wet and dry processing methods to obtain approximately 1kg of clean green coffee beans. Finally, 300gm clean coffee was taken from 1kg clean coffee bean of each sample for the physical and sensorial analysis of quality.

Sample preparation

The samples used for dry processing were properly dried on purposely built wire mesh raised table to a uniform moisture content of 11.5%. All the necessary attention (like equal amount of coffee cherries for each and equal partition of the wire mesh raised table) was given to the thickness of drying layers and cherries were turned regularly to maintain uniform drying. When drying was completed, samples were carefully packed and labeled for the subsequent operation. The dried coffee cherries were dehusked using a lab-scale hulling machine to produce the clean coffee beans needed for further analysis.

The samples used for wet processing were prepared as per the recommendation (Behailu *et al.*, 2008b). First, the harvested red ripe cherries were dipped into water to sort floater cherries and then pulped using a hand operating pulping machine at JARC. The parchment coffee obtained after pulping was separated from the pulps and floater beans by dipping it again into water. The heavier parchment coffee was allowed to ferment in the fermentation bucket for 48 hrs, and thereafter the pectic substance (slippery mucilage) was washed off with clean water. It also further socked in clean water for additional 24hrs, and received its final wash. Following the processes of fermentation and washing, it was dried on raised wire mesh tables to a uniform moisture content of 11.5%, which was measured by moisture tester (H-E50, Germany). Ultimately, the dried parchment coffee was hulled and polished to get clean coffee beans for quality analysis.

After drying, all coffee samples processed in dry and wet processing were packed into small plastic bags and properly labeled for the laboratory analysis of quality attributes, which was held in the coffee liquoring laboratory of JARC. For raw and cup quality analysis by the panelists, each sample was coded with number in order to avoid the "Hallo" effect among panelists about the nature of the samples.

Roasting and Grinding

About 100g of green coffee bean per sample was used for roasting. Each sample was separately roasted up to medium level (until the color of coffee beans became brown) for about 7 minutes by using roaster machine (Probat BRZ6, Germany) with a cylinder heat of 150-200^{0}C. When roasting was considered medium, the coffee beans were tipped out in to the cooling tray and allowed to cool for about 4 minutes. After cooling and before grinding, the samples were blown to remove the loose silver skins. Ten gram of roasted bean for each cup was ground immediately before brewing using electrical coffee grinder (MahlKonig, Germany) with middle adjustment to get fine to medium size coffee powder.

Preparation for liquoring

Three cups each with 8g of coffee powder were prepared for each sample for liquoring. The boiling distilled water was poured half of the cup with 8g of coffee powder, and thereafter the volatile aromatic quality and intensity parameters were recorded by sniffing. The cups were then filled with boiled water and after 3 minutes, the surface of the beverage of each cup has been skimmed off with spoon to remove the foam and made ready the beverage for testing.

3.5. Data Collection

As per the objectives of this study, pertinent data were collected on all quality attributes of green bean (screen size, bean weight, moisture, shape and make, and color) and cup (aromatic quality, aromatic intensity, acidity, body, flavor, astringency and overall characteristics) as per the standard recommendation of ISO (2000).

Moisture testing

Testing of the moisture content of coffee bean is a standard quality evaluating parameter to start the next steps of quality evaluation processes and to check if it is conducive for the effect of microbial action, particularly for Ochratoxin. It was measured by using the moisture tester from powders of 50 clean green beans taken from each sample. Then, the following data were considered for evaluation of coffee quality as per the standard procedures of ISO (2000).

Physical characteristics

Bean size, weight, shape and make, and color are some of the physical characteristics of the green coffee beans, which are used to estimate the quality of the raw coffee beans.

Screen analysis (bean size ≥ 14 inch sieve): has been measured by taking 100g of beans, and then passed it through a sieve with round perforations of 14 inches. The weight fractions retained on sieve ≥ 14 inches were recorded and converted to weight percentages of the total sample.

Mean bean weight: randomly taken hundred coffee beans from each sample were dried in the oven for 24 hours at temperature of 103^{o}C to bring the moisture content to zero (to control the moisture differences). After oven drying, the weight of the 100 beans of each sample was measured by using sensitive balance and then adjusted it into the bean weight at 11% moisture content by the following formula: bean weight at 0% moisture*100/bean number*0.89=bean weight at 11% moisture content (IPGRI, 1996).

Shape and make: shape uniformity and size of the beans, i.e., the presence of pea berries, round shape beans, broken beans, and shelled beans, were evaluated by using visual rating as 15=very good, 12=good, 8=average, 5=mixed and 2=small.

Color: The color of the beans was also evaluated by visual inspection method ranging from 2 to 15, where 2 = Brownish, 5 = Faded, 8 = Greenish, 12 = Grayish, and 15 = Bluish.

Organoleptic characteristics

Organoleptic quality was tested by trained panelists who are certified by Ministry of Agriculture Coffee Liquoring Unit, Addis Ababa, Ethiopia. Tasting was carried out once the beverage cooled to around 60^0C (drinkable temperature). Three cups per sample were prepared for a tasting session. Each of the five panelists had tasted and gave their own judgment separately for all three replications and mean of each variable by the panel was used for analysis. But, variation among assessors for a given variable was not considered.

Aromatic intensity, aromatic quality, acidity, body, flavor and astringency (sensorial vocabulary is presented in Appendix I) were scored using scales ranging from 0 to 5 where 0=nil,1=very light, 2=light,3=medium,4=strong and 5=very strong.

Data on overall standard for liquor quality were also taken based on the above attributes that ranges from 0 to 5, where, 0 = unacceptable, 1= bad, 2 = regular, 3 = good, 4 = very good, 5 = excellent.

3.6. Data Analysis

Data were subjected to analysis of variance (ANOVA) for CRD factorial design using SAS computer software version 9.2 (SAS Institute, 2008). Analysis of variance was done after testing the ANOVA assumptions. Before pooling the data across environments, test of homogeneity for error of variance was done. Results obtained from the test of homogeneity for error of variance were found to be non significant for all quality parameters. Thus, the hypothesis that the two error variances are homogeneous is accepted (Gomez and Gomez, 1984) and (Rangaswamy, 1995). Therefore, the data was pooled across locations. As a result, the analysis of variance and other statistical analysis were run together by combining the two locations. Whenever, the results showed significant value, LSD was used to separate the treatment means.

4. RESULTS AND DISCUSSION

A study was conducted to assess the effect of different processing methods on the physical and organoleptic quality of arabica coffee hybrids, their parental lines and local coffee grown under research and farmers' field in two locations in Jimma zone. The analysis of variance for different quality parameters are presented in Appendix Tables II and III, and the findings of the investigation are presented and discussed under the following different sub-headings.

4.1. Physical Quality Parameters

4.1.1. Shape and make

The shape and make of the green bean is very important quality parameter in coffee quality assessment. A coffee of acceptable quality is expected to have uniform shape and make. In the present investigation, shape and make was not affected by the type of variety and locations as well as the interaction effects between location and processing method, and variety and processing method. On the contrary, it was found to be highly significantly ($P<0.01$) affected by processing methods and the interaction between location and variety. Significant ($P<0.05$) difference was also observed by the interaction among location, variety and processing methods (Table 3).

Table 3. P-values of location, variety, processing method and interactions for organoleptic and physical quality attributes of hybrids and their parental lines of arabica coffee

Source	Loc	Var	Pro	Loc* Var	Loc*Pro	Var*pro	Loc*Var*Pro	CV (%)
DF	1	6	1	6	1	6	6	
Physical attributes								
SM	0.8775	0.3746	**<.0001**	**0.0089**	0.0913	0.2869	**0.0123**	10.92
HBW	0.3043	**0.0036**	0.1692	**<.0001**	0.1393	0.4942	**0.0051**	5.44
ABS	0.8926	**<.0001**	0.9902	**<.0001**	0.5685	0.5619	**0.0020**	1.86
CL	0.0800	0.1665	**<.0001**	0.8458	0.1044	0.2342	0.2052	9.99
Organoleptic attributes								
AI	0.7632	0.8220	0.6813	0.1633	0.5077	0.3974	0.0550	10.16
AQ	0.2476	0.3155	0.8972	0.0970	0.4926	0.0744	**0.0358**	13.47
AC	0.2314	0.3850	0.9360	0.3092	0.5433	0.6940	0.2517	14.80
AS	0.2988	0.6074	0.6957	0.6996	0.7948	0.1041	0.3722	124.94
BO	0.7708	**0.0255**	**0.0260**	0.4167	0.1293	0.4414	0.4201	9.91
FL	0.5461	0.3457	0.5189	0.1262	0.1501	0.4306	0.4139	15.26
OAS	0.2861	0.1047	0.2273	0.0869	0.3137	0.5370	0.1236	12.89

Loc = Location Var = variety, Pro = processing method, SM = Shape and make, HBW = Hundred bean weight, ABS = Above screen size 14", CL= Color, AI=Aromatic intensity, AQ = Aromatic quality, AC= Acidity, AS= Astringency, BO=Body, FL= Flavor, OAS = Overall standard

Statistically, maximum value (15.00) that indicates a very good shape and make with uniform appearance was detected from the interaction effects of Seka * Gawe * Dry, Manna * 74110 * Wet, Manna * Dessu * Wet and Seka * Melko-CH2 * Wet (Table 4). However, these results were also statistically similar with shape and make registered from Manna * 74110 * Dry, Seka * Ababuna * Dry, Manna * Ababuna * Wet, Manna * Melko-CH2 * Wet, Manna * Gawe * Wet, Manna * Local * Wet, and wet processed 741, 74110, Ababuna, Gawe and Local from Seka. The minimum value (10.66), which is fairly good for shape and make, was recorded for Seka * 74110 * Dry; it however, did not statistically differ from dry processed 741, Dessu, Ababuna, Melko-CH2, Gawe and Local coffee from Manna; Seka * 741 * Dry, Seka * Dessu * Dry, Seka * Melko-CH2 * Dry, Seka * Local * Dry, Manna * 741 * Wet and Seka * Dessu * Wet (Table 4). This corroborates with Bertrand *et al.* (2004); Mekonen (2009) and Sivetz and Dosrosier (1979) who pointed out similar variability due to botanical variety and environmental growth circumstances. Similarly, Barel and Jacquet (2006) reported the presence of significant difference in mean performance among *Coffea arabica* L. genotypes for physical quality attributes like shape and make of coffee bean.

Table 4. Mean performance of interactions among location, variety and processing method for SM, HBW and ABS

Loc * Var * Pro	SM	HBW (g)	ABS (%)
Mana *741 * Dry	12.00bcd	13.26defghi	95.43cdefgh
Mana * 74110 * Dry	13.33abc	13.13efghi	98.10ab
Mana * Dessu * Dry	12.00bcd	13.83bcdef	95.06efghi
Mana * Ababuna * Dry	11.33cd	12.43ij	92.90hij
Mana * Melko-CH2 * Dry	12.00bcd	13.66bcdefg	95.60bcdefg
Mana * Gawe * Dry	11.33cd	11.86j	93.63ghij
Mana * Local * Dry	11.33cd	14.50b	92.96hij
Seka * 741 * Dry	12.00bcd	12.53hij	94.83efghi
Seka * 74110 * Dry	10.66d	12.76fghij	91.80j
Seka * Dessu * Dry	11.33cd	14.40bc	93.60ghij
Seka * Ababuna * Dry	14.00ab	14.23bcd	96.96abcde
Seka * Melko-CH2 * Dry	12.00bcd	13.10efghi	97.76abcd
Seka * Gawe * Dry	15.00a	15.63a	97.86abc
Seka * Local * Dry	12.00bcd	12.70ghij	92.60ij
Mana * 741 * Wet	12.00bcd	13.73bcdefg	95.93abcdefg
Mana * 74110 * Wet	15.00a	14.26bcd	98.36a
Mana * Dessu * Wet	15.00a	13.86bcde	91.80j
Mana * Ababuna * Wet	14.00ab	12.53hij	94.30fghij
Mana * Melko-CH2 * Wet	14.00ab	14.43bc	96.43abcdef
Mana * Gawe * Wet	14.00ab	13.36cdefghi	95.23defgh
Mana * Local * Wet	13.00abc	13.56bcdefgh	92.96hij
Seka * 741 * Wet	13.00abc	12.66ghij	93.00hij
Seka * 74110 * Wet	14.00ab	13.23defghi	95.26defgh
Seka * Dessu * Wet	12.00bcd	14.50b	95.73bcdefg
Seka * Ababuna * Wet	13.00abc	13.86bcde	95.13efghi
Seka * Melko-CH2 * Wet	15.00a	13.83bcdef	95.56bcdefg
Seka * Gawe * Wet	13.00abc	13.96bcde	95.70bcdefg
Seka * Local * Wet	14.00ab	13.36cdefghi	93.63ghij
LSD (5%)	2.08	1.07	2.55
CV (%)	10.92	5.44	1.86

Mean values followed by the same letter in the same column are not significantly different at P=0.05 probability level

Loc=Location, Var=Variety, Pro=Processing method, SM= Shape and make, HBW=Hundred bean weight, ABS= Above screen size 14"

4.1.2. Bean weight

Hundred bean weight (HBW) is used to compare and analyze the weight of coffee bean for each variety in terms of mean bean weight. The heavier the bean, the better it is in terms of quality. As indicated in Table 3, the hundred bean weight was significantly ($P<0.01$) affected by the three-way interaction effect of location, variety and processing method, but not by the main effects of location and processing method. Accordingly, the maximum HBW (15.63g) was measured for Seka * Gawe * Dry, followed by Manna * Local * Dry and Seka * Dessu * Wet (14.50g) whereas the minimum (11.86g) was registered from Manna * Gawe * Dry which, however, did not statistically differ from Manna * Ababauna * Dry, Seka * 741 * Dry, Seka * 74110 * Dry, Seka * Local * Dry, Manna * Ababuna * Wet and Seka * 741 * Wet (Table 4). The result of this study is in accordance with the previous works compiled by Wintgens (2004) in terms of varieties' diversity of arabica coffee in average bean weight values which ranges between 18.2g and 9.2g. Yigzaw (2005) also reported the diversity of *Coffea arabica* varieties in their average bean weight performance.

4.1.3. Bean size

Uniformity of bean size has a particular importance to roasters since it would be exposed to uniform roasting. Screen size is a standard method of describing the proportion of beans in terms of their size. Data analysis of the proportion of coffee beans retained on screen size $\geq$14" showed that the three-way interaction of location, variety and processing method significantly affected the percentage of beans above 14" screen size (ABS). The proportion of beans above this screen size was also significantly affected by the two-way interaction of location and variety (Table 3). Of all the treatment combinations, Manna * 74110 * Wet gave the highest (98.36) percentage of above screens. However, other treatments combinations, namely Seka * Gawe * Dry, Seka * Melko-CH2 * Dry, Seka * Ababuna * Dry, Manna * Melko-CH2 * Wet, Manna * 74110 * Dry and Manna * 741 * Wet were statistically identical with respect to producing more above screen beans (Table 4). On the other hand, above screen bean percentage was decreased to 91.80 due to the treatment combination Seka * 74110 * Dry and Manna * Dessu * Wet, which was still statistically similar with the values obtained from the treatment combinations of Manna * Ababuna * Dry, Manna * Gawe * Dry, Manna * Local * Dry, Seka * Dessu * Dry, Seka * Local * Dry, Manna * Ababuna * Wet, Manna * Local * Wet, Seka * 741 * Wet and Seka * Local * Wet. Generally, more than 91% of beans of all varieties was above 14 " screen size, indicating all varieties had a very good uniformity in bean size. Since the main effect of location and processing method was not significant, the discrepancy of varieties in terms of ABS in this study might be explained by the inherent genetic variations present among varieties, suggesting the possibility to improve this quality attribute of the crop through selection and cross breeding. Similar finding that is the influence of botanical variety and environmental growth circumstances on bean size were also reported by Yigzaw (2005). Selvakumar and Sreenivasan (1989) again observed coffee quality variation ranging from good to excellent among 54 arabica coffee accessions collected from Keffa province of Ethiopia. Bean size of coffee accessions collected from the same location revealed significant variation for different processing methods (Mekonen, 2009).

4.1.4. Color

The results presented in Table 3 explain that the color of coffee beans was highly significantly ($P<0.01$) affected by the type of processing method, regardless of the variety and the location of production, however all interaction effects including the three-way interaction were found to be non significant.

Table 5. Mean performance of processing methods for color

Processing method	Color
Wet	12.60[a]
Dry	10.71[b]
LSD (5%)	0.51
CV (%)	9.99

Mean values followed by the same letter in a column are not significantly different at P= 0.05 probability level

Relatively higher mean for color was registered from wet coffee processing method (12.60) than the dry processing method (10.71) (Table 5). Even though the result showed statistically significant variation, the mean values for color in both processing methods indicate nearly grayish color, which is the second most acceptable color in coffee quality next to bluish. This result implies that it is possible to get a similar quality coffee with that of wet processed coffee from dry processed coffee if dry processing method is properly used,. In contrast with this, other investigations showed quality differences of coffees of similar origin, but processed differently. For example, the best, clean and bright color was obtained from wet processed coffee (CRI, 2006; Mekonen, 2009), and the poorest color from that of dry processed coffee (Mekonen, 2009). Despite their similarity in ripening stage of the samples, it is also confirmed that processing method creates significant difference in the quality of coffee beans (Daniel, 2009).

4.2. Organoleptic Quality Parameters

4.2.1. Aromatic intensity

Based on the results of the present study depicted in Table 3, the aromatic intensity among the arabica coffee varieties, between processing methods and location showed non significant variation. Similarly there was no significant interaction effect between location and variety, location and processing method, variety and processing method as well as the three-way interaction. In contrast with this, Getu (2009) observed a significant difference among different coffee genotypes growing in different locations for acidity, aromatic intensity, flavor and overall standard. Walyaro (1983) also reported the presence of large performance difference among genotypes for cup quality attributes.

4.2.2. Aromatic quality

The aroma of coffee is responsible for all flavor attributes other than the mouth feel, sweet, salt and sour taste that are perceived by the tongue. As indicated in Table 3, the aromatic quality of coffee was not affected by the type of variety, location or processing method and the two-way interactions. However, the three-way interaction resulted in a significant (P<0.05) variation.

Table 6. Mean performance of interactions among location, variety and processing method for aromatic quality

Loc * Var * Pro	Aromatic Quality
Mana *741 * Dry	3.11bcdefg
Mana * 74110 * Dry	2.61fg
Mana * Dessu * Dry	3.00cdefg
Mana * Ababuna * Dry	3.66ab
Mana * Melko-CH2 * Dry	3.00cdefg
Mana * Gawe * Dry	2.91defg
Mana * Local * Dry	3.00cdefg
Seka * 741 * Dry	3.97a
Seka * 74110 * Dry	3.11bcdefg
Seka * Dessu * Dry	3.05bcdefg
Seka * Ababuna * Dry	2.97cdefg
Seka * Melko-CH2 * Dry	2.63fg
Seka * Gawe * Dry	3.38abcde
Seka * Local * Dry	3.33abcde
Mana * 741 * Wet	3.22bcdef
Mana * 74110 * Wet	3.33abcde
Mana * Dessu * Wet	2.94cdefg
Mana * Ababuna * Wet	3.58abc
Mana * Melko-CH2 * Wet	3.00cdefg
Mana * Gawe * Wet	3.05bcdefg
Mana * Local * Wet	2.50g
Seka * 741 * Wet	2.77efg
Seka * 74110 * Wet	3.11bcdefg
Seka * Dessu * Wet	3.22bcdef
Seka * Ababuna * Wet	3.11bcdefg
Seka * Melko-CH2 * Wet	3.44abcd
Seka * Gawe * Wet	3.19bcdef
Seka * Local * Wet	3.11bcdefg
LSD (5%)	0.65
CV (%)	13.47

Mean values followed by the same letter in the same column are not significantly different at P=0.05 probability level
Loc=Location, Var=Variety, Pro=Processing method

Significantly maximum value for aromatic quality (3.97), which means strong aromatic quality, was recorded as a result of the interaction among Seka * 741 * dry processing, which of course was on a par with Manna * Ababuna * Dry, Seka * Gawe * Dry, Seka * Local * Dry, Manna * 74110 * Wet, Manna * Ababuna * Wet and Seka * Melko-CH2 * Wet. On the other hand, statistically the lowest value (2.50), which means nearly medium aromatic quality, was registered for Manna * Local * Wet. That was statistically identical with dry processed 741, 74110, Dessu, Melko-CH2, Gawe and Local coffee from Manna, dry processed 74110, Dessu, Ababuna and Melko-CH2 from Seka, wet processed Dessu, Melko-CH2 and Gawe from Manna, wet processed 741, 74110, Ababuna and Local coffee from Seka (Table 6). Some evidences indicated that some liquor characteristics such as aromatic quality, aromatic intensity, acidity and flavor have been predetermined by genetic and environmental factors prior to processing (Brownbridge and Michael, 1971; Getu, 2009). Similarly, Vossen (1985) observed variation for cup quality characters among varieties and crosses of arabica coffee.

4.2.3. Acidity

The acid content in a brew is greatly dependent upon the degree of roast, type of roast and brewing method. Anaysis of varaiance showed non significant variation among the varieties, and between processing methods and locations as well as their two-and three-way interactions for acidity (Table 3). In contrary, Getu (2009) observed significant difference for different coffee genotypes and different locations for acidity, aromatic intensity, flavor and overall standard. Similarly, Yigzaw (2005) found variations in acidity among coffee genotypes collected from different parts of Ethiopia. Moreover, Jackelers and Jackels (2005) noted the breakage of cellulose of the mucilage and the increment of acidity due to fermentation in wet processed coffee.

4.2.4. Astringency

There was no significant variation observed for astringency among the arabica coffee varieties, between processing methods and location. Similarly, there were no significant interaction effects for all factors under study (Table 3). In contrast to this, environmental variation had large effect on the expression of astringency, bitterness and flavor of coffee (Getu, 2009).

4.2.5. Body

Body implies impression of consistency given by the coffee brew. Based on the results of the present study (Table 3), body was found to be non significant for location and all interaction effects; but, it was significantly affected by variety and processing method.

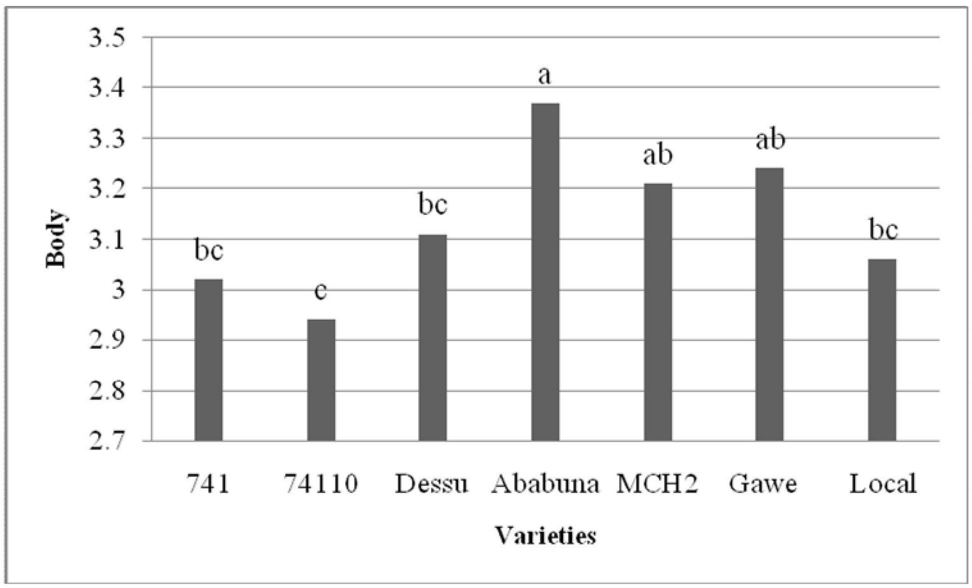

Figure 1. Mean performance of coffee varieties for body. *Mean values followed by the same letter on the bar graphs are not significantly different at P = 0.05 probability level*

Regardless of the location and the processing method, the maximum value for body (3.37), which indicates a medium standard of body, was observed for variety Ababuba, which was statistically on a par with varieties Melko-CH2 (3.21) and Gawe (3.24). Whereas the minimum value (2.94), which is also in the range of medium standard, was registered for variety 74110. The value 2.94 was more or less statistically equal with the values obtained from varieties Dessu (3.11), Local (3.06) and 741 (3.02) (Figure 1; Appendix Table IV). Although the body found for some variety was statistically different, it was in the medium range for all varieties that indicates similarity of all varieties for body. Similarly, Walyaro

(1983) and Vossen (1985) reported the presence of differences among arabica coffee varieties for cup quality attributes like body. Roche (1995) also observed significant differences among different arabica coffee cultivars and crosses for various cup quality attributes including body.

Statistically higher mean body (3.21) was found for wet processing and the lowest (3.06) for dry processing method (Table, 7). However, similar to the variations among varieties for this attribute as described above, these values (3.21 and 3.06) of body for both processing methods felled in the medium range, indicating both processing methods gave similar quality in terms of body. Unlike to this result, Anwar (2010) reported high mean values of acidity, body and flavor for wet processing method as compared to dry processing method. While other findings showed that the dry processed coffees are heavy in body (CRI, 2006).

Table 7. Mean performance of processing methods for body

Processing method	Body
Wet	3.21[a]
Dry	3.06[b]
LSD (5%)	0.14
CV (%)	9.91

Mean values followed by the same letter in the same columns are not significantly different at P = 0.05 probability level

4.2.6. Flavor

The flavor obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee. As indicated in Table 3, there was no significant variation in the flavor among main effects such as varieties, processing methods and locations as well as their interactions. However, Getu (2009) observed significant difference for different coffee genotypes and locations for acidity, aromatic intensity, flavor and overall standard. In addition, the flavor variations between a dry processed and wet processed coffee was typically more vivid than the flavor differences among different locations (Guyot, 2001). If every stage of processing goes well the regional distinctions become prominent, but the defect produced will ambiguous the regional distinctiveness if there is some fault in any step along the processing chain.

4.2.7. Overall standard

Overall organoleptic quality measurement relies on sensory evaluation. There was no significant variation in the overall quality standard among varieties, between processing methods and locations, and all the interactions of the three factors (Table 3). However, Getu (2009) observed significant difference for different coffee genotypes and different locations for acidity, aromatic intensity, flavor and overall standard. Variation on overall quality among varieties due to processing method and the environment in which the varieties grown was also reported (Moreno *et al.,* 1995 and Yigzaw, 2005). In other study, the interaction of genotype by processing method had significant effect on the overall quality of coffee (Mekonen, 2009).

4.3. Correlation studies

The correlation among each physical parameters of coffee bean was positive and non significant ($0.0<r<0.5$) except between shape and make (SM) and above screen 14" (ABS), which was significant ($r=0.64$). Each physical attributes was also non-significantly correlated with each cup quality attributes. Similarly, all cup quality attributes, except aromatic intensity that was negatively correlated, was positively and non-significantly correlated with color ($0.0<r<0.5$). Whereas the correlation between ABS, SM and all cup quality attributes, hundred bean weight (HBW) and all cup quality attributes except astringency, and astringency and all bean quality attributes except HBW and color were negative and non significant ($0.0>r>-0.5$). However, there was a significant and positive correlation among each of the cup quality attributes ($r>0.5$) except astringency and body with other quality attributes and with each other (Table 8).

Almost all cup quality attributes except astringency were positively correlated with each other. This is in line with the finding of Kathurima *et al*. (2009) who showed the significant and positive correlations between different sensory characteristics, indicating that any one characteristic is an important component of beverage quality. Yigzaw (2005) also found positive correlations between cup quality attributes. The non significant correlation between beverage quality and bean physical characteristics is in agreement with the research result by

Agwanda *et al*. (2003) who reported non-usefulness of bean quality traits for enhancement of genetic gains on cup quality. Yigzaw (2005) also reported green bean physical characters are not good indicators for cup quality improvement. The positive correlation of body with the physical quality attributes, as did color with cup quality attributes was similar with the result of that of Mekonen (2009). He reported positive correlation of body with bean weight and size, and color with acidity, body and total quality.

Table 8. Bi-variat correlation coefficients between coffee quality attributes

	HBW	SM	CL	ABS	AI	AQ	AC	AS	BO	FL	OAS
HBW											
SM	0.24^{ns}										
CL	0.49^{ns}	0.37^{ns}									
ABS	0.45^{ns}	0.64*	0.17^{ns}								
AI	-0.33^{ns}	-0.38^{ns}	-0.01^{ns}	-0.45^{ns}							
AQ	-0.49^{ns}	-0.07^{ns}	0.12^{ns}	-0.12^{ns}	0.60*						
AC	-0.45^{ns}	-0.29^{ns}	0.03^{ns}	-0.10^{ns}	0.63*	0.87**					
AS	0.36^{ns}	-0.41^{ns}	0.15^{ns}	-0.01^{ns}	-0.18^{ns}	-0.01^{ns}	-0.12^{ns}				
BO	-0.19^{ns}	-0.03^{ns}	0.42^{ns}	-0.27^{ns}	0.49^{ns}	0.37^{ns}	0.12^{ns}	-0.09^{ns}			
FL	-0.46^{ns}	-0.13^{ns}	0.03^{ns}	-0.36^{ns}	0.65*	0.83**	0.78**	-0.26^{ns}	0.43^{ns}		
OAS	-0.34^{ns}	-0.21^{ns}	0.20^{ns}	-0.30^{ns}	0.72**	0.89**	0.82**	-0.11^{ns}	0.60*	0.92**	

Ns,,** indicates the correlation value is non significant, significant, and highly significant, respectively at P = 0.05 probability level. HBW= hundred bean weight, SM= shape and make, CL= color, ABS= above screen 14", AI= aromatic intensity, AQ= aromatic quality, AC= acidity, AS= astringency, BO= body, FL= flavor, OAS= overall standard.*

5. SUMMARY AND CONCLUSIONS

Arabica coffee is by far the most economically important species in the world coffee market. Ethiopia is endowed with immense potential of diverse coffee genotypes and contrasting ecological condition for coffee cultivation. But, the national average coffee yield remains low as compared to other coffee producing countries. Since the inception of hybridization program; a considerable amount heterosis for yield has been observed over the better parent and the average yield of the hybrids was consistently higher than that of parental mean. In effect, three coffee hybrids; namely, Ababuna, Melko-CH2 and Gawe have been released for medium altitude areas of southwestern Ethiopia. And the quality of these hybrids was found to be acceptable under research stations, but little has been known about their quality under on-farm conditions.

The specific objective of the experiment was, therefore, to determine the effects of processing methods on the bean physical and organoleptic quality attributes of these arabica coffee hybrid varieties growing on-farm conditions at Koffe and Haro and their parental lines growing on the nearest research station of the two sites in Jimma zone. The analysis of the physical and sensorial quality characters of the bean for 7 varieties (3 hybrids: Ababuna, Gawe and Melko-CH2; 3 parental lines: 741, 74110 and Dessu; and a local variety from each locations) has been performed at Jimma Agricultural Research Center by selectively harvesting red ripe cherries and processing by Wet and Dry methods. The treatments and their finals results were evaluated using CRD with factorial arrangement in 3 replicates.

The results indicated that body from organoleptic quality parameters and hundred bean weight and above screen size from physical quality parameters had significant difference among varieties. Even if the figures for body were statistically significant, all varieties had medium body. Similarly, body and color demonstrated statistically significant differences between the processing methods; but coffees processed by both processing methods were grayish in color and medium in body. Moreover, all organoleptic quality parameters except body were not significantly affected by both variety and processing method. This may imply that dry processed coffee can have comparable quality with that of wet processed coffee if fully red ripe cherries are selectively picked and properly dried to the desired moisture content on raised beds. The non-significant variation for all quality attributes between locations, and its two-way interaction with variety and processing method indicates the smaller agroecological difference between these two locations (Mana and Seka) to bring variations in coffee quality performance among varieties.

The interaction effect of location by variety was found to be significant only for shape and make, hundred bean weight and above screen size whereas all other two-way interactions were non significant for all the remaining quality parameters. Aromatic quality, shape and make, hundred bean weight and above screen size were the only significant results recorded due to the three-way interaction effects (location *variety *processing method). Seka * Gawe * Dry, Manna * 74110 * Wet, Manna * Dessu * Wet and Seka * Melko-CH2 * Wet had very good shape and make with uniform appearance. Statistically the highest bean weight was obtained from dry processed Gawe variety growing in Seka (Seka * Gawe * Dry). Following Gawe, wet and dry processed Dessu variety growing in same site gave higher bean weight. Regardless of the location and processing methods, the varieties 74110 and Melko-CH2, scored better bean size followed by Gawe, Ababuna and 741 in that order. The combinations of Manna *Ababuna * Dry and Seka *741 * Dry showed the highest mean for aromatic quality, which was strong; and all other treatment combinations had reflected medium values. There were also significant and positive correlations among most of the cup quality attributes except between astringency and body with other cup quality attributes. But the correlation of each physical (except color) and cup quality attributes was negative and non-significant. Therefore, it could be difficult to use green bean physical attributes for cup quality improvement and vice versa.

As a whole, regardless of locations and processing methods, it can be concluded that coffee varieties 74110, Dessu, Melko-CH2 and Gawe had an excellent value in some of the significantly affected quality attributes (hundred bean weight, above screen size 14 and body) and followed by Ababuna. Since two of the hybrid varieties and two of the selections had relatively excellent values for some of these quality attributes, it can avoid the previous misconception of the growers about inferiority of the improved varieties in quality.

Since the study was conducted on only few (seven) varieties at two locations in one season and focused on some physical and sensory quality attributes, it needs further research on more varieties over seasons and locations including biochemical bean quality attributes that have not considered in this study; and in depth investigation of the relationship among physical and sensory coffee bean quality attributes and the performance of the hybrid varieties and parental lines under famers' field conditions.

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7. APPENDICES

Appendix Table I The standard sensorial analysis vocabulary used for the study

I General terminologies	Definition
Sensory analysis	Examination of organoleptic attributes of a product by the sense organs
Sensory	Relating to the use of sense organs
Organoleptic	Relating to an attribute of a product perceptible by the sense organs
Panel	Group of assessors chosen to participate in sensory test
Attribute	Perceptible characteristic
Intensity	The magnitude of the perceived sensation The magnitude of the stimulus causing the perceived sensation
II Terminology relating to organoleptic attributes	
Acid (taste)	Describes the basic taste produced by dilute aqueous solutions of most acid substances (e.g., citric acid and tartaric acid)
Acidity	Organoleptic attribute of pure substances or mixtures which produces the acid taste
Bitter (taste)	Describes the basic taste produced by dilute solutions of various substances such as quinine and caffeine
Flavor	Complex combination of the olfactory and trigeminal sensations perceived during tasting. Flavor may be influenced by tactile, thermal, painful, and unaesthetic effects
Mouth feel	The tactile sensations perceived at the lining of the mouth, including the tongue, gums and teeth
Body	Richness of flavor or impression of consistency given by a product
Astringent	Describes complex sensation accompanied by shrinking, drawing or puckering mucosal surface in the mouth, produced by substances like tannins sloe tannins
Astringency	Organoleptic attribute of pure substances or mixtures which produces the astringency
Aroma	French sense: organoleptic attribute perceptible by the olfactory organ via the back of the nose when tasting

Source: ISO (2004)

Appendix Table II Mean squares of location, variety, processing method and interactions for physical and organoleptic quality attributes over location

Source	Loc	Var	Pro	Loc*Var	Loc*Pro	Var*Pro	Loc*Var*Pro	Error
DF	1	6	1	6	1	6	6	54
Physical attributes								
SM	0.04^{ns}	2.17^{ns}	45.76**	5.18**	4.76 ^{ns}	2.51 ^{ns}	4.90*	1.61
CL	4.29^{ns}	2.15^{ns}	74.29**	0.60 ^{ns}	3.44 ^{ns}	1.88 ^{ns}	1.85 ^{ns}	1.26
HBW	0.58^{ns}	1.59**	1.05^{ns}	5.01**	0.96 ^{ns}	0.49 ^{ns}	1.51**	0.42
ABS	0.05^{ns}	15.45**	0.00^{ns}	19.34**	0.80 ^{ns}	2.55 ^{ns}	9.83**	2.43
Organoleptic attributes								
AI	0.01^{ns}	0.05^{ns}	0.01^{ns}	0.17^{ns}	0.04 ^{ns}	0.11 ^{ns}	0.21 ^{ns}	0.09
AQ	0.24^{ns}	0.21^{ns}	0.00^{ns}	0.33 ^{ns}	0.07 ^{ns}	0.36 ^{ns}	0.38*	0.15
AC	0.29^{ns}	0.21^{ns}	0.001^{ns}	0.24 ^{ns}	0.07 ^{ns}	0.13 ^{ns}	0.26 ^{ns}	0.19
AS	0.08^{ns}	0.05^{ns}	0.01^{ns}	0.04 ^{ns}	0.00 ^{ns}	0.14 ^{ns}	0.08 ^{ns}	0.07
BO	0.00^{ns}	0.25*	0.50*	0.09 ^{ns}	0.22 ^{ns}	0.09 ^{ns}	0.09 ^{ns}	0.09
FL	0.06^{ns}	0.21^{ns}	0.07^{ns}	0.32 ^{ns}	0.39 ^{ns}	0.18 ^{ns}	0.19 ^{ns}	0.18
OAS	0.16^{ns}	0.26^{ns}	0.21^{ns}	0.28 ^{ns}	0.13 ^{ns}	0.12 ^{ns}	0.23^{ns}	0.13

Ns,,**,indicate non- significant (p>0.05), * significant (P<0.05), **highly significant (P<0.01)*

Loc = Location Var = variety, Pro = Processing method, AI = Aromatic intensity, AQ = Aromatic quality, AC = Acidity, AS = Astringency, BO = Body, FL = Flavor, OAS = Overall standard, SM = Shape and make, CL= Color, HBW = Hundred bean weight, ABS = Above screen size 14"

Appendix Table III. Mean squares of variety, processing method and interactions for physical and organoleptic quality attributes at each location

Location	Manna					Seka				
Source	Var	pro	var*pro	error	C.V(%)	Var	Pro	Var*pro	error	C.V(%)
DF	6	1	6	26		6	1	6	26	
Physical attributes										
SM	3.43 ^{ns}	40.02**	1.52 ^{ns}	1.85	10.55	3.94*	10.50**	5.88**	1.30	8.83
CL	1.44 ^{ns}	54.86**	1.25 ^{ns}	0.88	8.21	1.32 ^{ns}	22.88**	2.49 ^{ns}	1.56	10.52
HBW	2.55**	2.01 ^{ns}	0.96 ^{ns}	0.56	5.60	4.06**	0.00 ^{ns}	1.03**	0.28	3.91
ABS	20.77**	0.38 ^{ns}	3.98 ^{ns}	1.95	1.48	14.03**	0.42 ^{ns}	8.40*	2.75	1.75
Organoleptic attributes										
AI	0.16^{ns}	0.01 ^{ns}	0.18 ^{ns}	0.13	11.20	0.07 ^{ns}	0.06 ^{ns}	0.15 ^{ns}	0.07	8.12
AQ	0.45*	0.02 ^{ns}	0.19 ^{ns}	0.16	13.27	0.09 ^{ns}	0.05 ^{ns}	0.54**	0.15	12.28
AC	0.31^{ns}	0.03 ^{ns}	0.14 ^{ns}	0.21	15.22	0.16 ^{ns}	0.05 ^{ns}	0.26 ^{ns}	0.18	13.83
AS	0.01^{ns}	0.00^{ns}	0.11 ^{ns}	0.06	129.02	0.10 ^{ns}	0.02 ^{ns}	0.12 ^{ns}	0.094	121.29
BO	0.29*	0.69**	0.16 ^{ns}	0.09	10.10	0.06 ^{ns}	0.03 ^{ns}	0.03 ^{ns}	0.09	9.40
FL	0.38^{ns}	0.41 ^{ns}	0.21 ^{ns}	0.19	15.70	0.17 ^{ns}	0.06 ^{ns}	0.18 ^{ns}	0.18	14.56
OAS	0.48*	0.35 ^{ns}	0.24 ^{ns}	0.17	14.16	0.07 ^{ns}	0.00 ^{ns}	0.12 ^{ns}	0.10	10.81

Ns,*,** *indicates non significant ($p>0.05$), significant ($p<0.05$) and highly significant ($p<0.01$), respectively*
Var= variety, Pro= processing method, AI= Aromatic intensity, AQ=Aromatic quality, AC= Acidity, AS= Astringency, BO=Body, FL= Flavor, OAS= Overall standard, SM= Shape and make, CL= Color, HBW= Hundred bean weight, ABS = Above screen 14".

Appendix Table IV Mean performance of Varieties for Body

Variety	Body
Ababuna	3.37a
Gawe	3.24ab
Melko-CH2	3.21ab
Dessu	3.11bc
Local	3.06bc
741	3.02bc
74110	2.94c
Mean	3.14
LSD (5%)	0.25
CV (%)	9.91

Mean values followed by the same letter in columns are not significantly different at p = 0.05 probability level

Appendix Table V. Cup quality and green bean physical characteristics evaluation of the coffee samples for grading

Sample code	Raw quality				Cup quality				
	SM(10)	CL(5)	DC	OD(5)	CC(15)	AC(15)	BO(15)	FL(15)	OVQ
741 Manna			0	10	11	15	9	9	2nd
74110 Manna			0	9	9	9	9	9	3rd
Dessu Manna			0	9	9	9	9	9	3rd
Ababauna Manna			0	9	12	12	12	12	2nd
Melko-CH2-2 Manna			0	9	10	12	9	9	3rd
Gawe Manna			0	10	10	9	12	9	3rd
Local Manna			0	10	9	9	9	9	3rd
741 Seka			0	9	10	12	9	9	3rd
74110 Seka			0	9	9	9	9	9	3rd
Dessu Seka			0	10	9	9	9	9	3rd
Ababauna Seka			0	10	9	9	9	9	3rd
Melko-CH2 Seka			0	10	8	9	9	6	3rd
Gawe Seka			0	10	9	9	9	9	3rd
Local Seka			0	10	9	9	9	9	3rd
741 Manna	8	4	0	5	10	12	9	9	3rd
74110 Manna	10	4	0	5	9	9	9	9	3rd
Dessu Manna	10	5	0	5	9	9	9	9	3rd
Ababauna Manna	9	4	0	5	11	12	12	9	2nd
Melko-CH2 Manna	9	4	0	5	9	9	9	9	3rd
Gawe Manna	9	4	0	5	9	9	9	9	3rd
Local Manna	7	4	0	5	9	9	9	9	3rd
741 Seka	7	4	0	5	9	9	9	9	3rd
74110 Seka	9	4	0	5	9	9	9	9	3rd
Dessu Seka	8	4	0	5	9	9	9	9	3rd
Ababauna Seka	7	4	0	5	9	9	9	9	3rd
Melko-CH2 Seka	10	5	0	5	9	9	9	9	3rd
Gawe Seka	9	5	0	5	9	9	9	9	3rd
Local Seka	9	4	0	5	9	9	9	9	3rd

DC= defects count; SM= shape and make; OD= odor; CL= color; AC= acidity; BO= body; FL= flavor; CC= cup cleanness; OVQ= overall quality

Appendix Table VI. Standard parameters and their respective values used for washed coffee raw quality evaluation and grading as per (ECX, 2010)

Raw value (40%)									
Defects (20%)				Shape and make (10%)		Color (5%)		Odor (5%)	
Primary (count) (10%)	pts	Secondary (weight) (10%)	pts	Quality	pts	Quality	pts	Quality	pts
0	10	<5%	10	V. Good	10	Bluish	5	Clean	5
1-4	8	<8%	8	Good	8	Grayish	4	F. Clean	4
5-6	6	<10%	6	F. Good	6	Greenish	3	Trace	3
7-10	4	<12%	4	Average	4	Coated	2	Light	2
11-15	2	<14%	2	Fair	2	Faded	1	Moderate	1
>15	1	>14%	1	Small	1	White	0	Strong	0

Cup value (60%)

Cup cleanness (15%)		Acidity (15%)		Body (15%)		Flavor (15%)	
quality	pts	Intensity	pts	Quality	Pts	Quality	pts
Clean	15	Pointed	15	Full	15	Good	15
F .clean	12	M. Pointed	12	M. Full	12	F .Good	12
1CD	9	Medium	9	Medium	9	Average	9
2CD	6	Light	6	Light	6	Fair	6
3CD	3	Lacking	3	Thin	3	Commonish	3
>3CD	0	ND	0	ND	0	ND	0

Grade range: grade1=91-100; grade2=81-90; grade3=71-80; grade4=63-70; grade5=58-62; grade6=50-57; grade7=40-49; grade8=31 39;grade 9=20-30; under grade=15-19; CD= Cup defect; ND= Not detected; F=Fair; M= Medium

Appendix Table VII Standard parameters and their respective values used for unwashed coffee raw quality evaluation and grading as per ECX (2010)

Raw value (40%)						Cup value (60%)							
Defects (30%)				Odor (10%)		Cup cleanness (15%)		Acidity (15 %)		Body (15%)		Flavor (15%)	
Primary (count) (15%)	Pts	Secondary (wt) (15%)	Pts	Quality	Pts	Quality	Pts	Intensity	Pts	Quality	Pts	Quality	Pts
<5	15	<5%	15	Clean	10	Clean	15	Pointed	15	Full	15	Good	15
6-10	12	<10%	12	F. Clean	8	F. Clean	12	M. Pointed	12	M .full	12	F. Good	12
11-15	9	<15%	9	Trace	6	1 CD	9	Medium	9	Medium	9	Average	9
16-20	6	<20%	6	Light	4	2 CD	6	Light	6	Light	6	Fair	6
21-25	3	<25%	3	Moderate	2	3 CD	3	Lacking	3	Thin	3	Commonish	3
>25	1.5	>25%	1.5	Strong	0	>3 CD	0	ND	0	ND	0	ND	0

Grade range: grade1=91-100; grade2=81-90; grade3=71-80; grade4=63-70; grade5=58-62; grade6=50-57; grade7=40-49; grade8=31 39;grade 9=20-30; under grade=15-19; CD= Cup defect; ND= Not detected; F=Fair; M= Medium

Appendix Table VIII. Standard parameters and their respective values used for unwashed and washed coffee raw and cup quality evaluation as per JARC (A data format)

Character	Sample code							
Shape and make								
Color								
Odor								
Moisture content								
Over screen 14”								
Aromatic intensity								
Aromatic quality								
Acidity								
Astringency								
Bitterness								
Body								
Flavor								
Typicity								
Overall standard								
Defects								
Remark								

Notes: Shape and make (15) where 15= V. good, 12=Good, 8=Average, 5=Mixed, 2=Small
Color (15) where 15=Bluish, 12= Grayish, 8=Greenish, 5=Faded, 2=Brownish
Odour (10) where 10= clean, 8=Trace, 5=Light, 2=Moderate, 1=Strong
Scale ranging from 0-5 where 0=nil, 1= very light, 2=light, 3=medium, 4=Strong, 5=very strong
**Typicity is an after taste aromatic quality that could be winey, citrus, mocha fruity, spicy*
Overall standard is evaluated based on the other attributes (aromatic quality, acidity, body, flavor and typicity).
For overall standard, scale ranging from 0-5 where, 0 = unacceptable, 1 = bad, 2 = regular, 3=good, 4 = very good, 5 = Excellent.

Appendix Figure I. Partial view of recommended method of dry processing

Appendix Figure II. Partial view of recommended method of wet processing

Appendix Figure III. Measuring of coffee samples for different laboratory activities by using sensitive balance

Appendix Figure IV. Displayed coffee samples for cup test


Appendix Figure V. Professional coffee testers of JARC, cupping for quality evaluation