EFFECT OF SUN DRYING METHODS AND LAYER THICKNESS ON QUALITY OF SELECTED UNWASHED ARABICA COFFEE VARIETIES IN JIMMA ZONE

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By

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DEDICATION

I dedicate this thesis to my beloved children: Bethlehem and Daniel Berhanu for all the sacrifices, wishes and praiseworthy to success in all my endeavors.

STATEMENT OF THE AUTHOR

I, the undersigned declare that this thesis is my work and that all sources of the materials used for this thesis have been duly acknowledged. This thesis has been submitted to impartial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

Berhanu Tsegaye Woldeyohannes was born on September 22, 1970 at the vicinity of Shambu town, Horo Guduru Wellega Zone. He attended his education at Shambu Elementary School and Secondary High School from 1976 to 1986, respectively. He joined Awassa Junior College of Agriculture (now Hawassa University) in 1986 and graduated in 1987 with a Diploma in Plant Science and Technology. He was employed on December, 1988 by Higher Education Main Department and assigned to the then Asmara University (now Eritrea) to serve as Technical Assistant in Arid Zone Agriculture Department. Since May, 1989 he was again transferred to the Ministry of Coffee and Tea Development to serve as Subject Matter Specialist and worked in various disciplines and at different districts of Jimma zone. He joined Jimma University, College of Agriculture and Veterinary Medicine in 2004 and graduated in 2008 with a B.Sc. degree in Horticulture. Later on, he joined Jimma University College of Agriculture and Veterinary Medicine School of Graduate Studies on September, 2009 to pursue his M.Sc. degree in Horticulture specializing in Coffee, Tea and Spices.

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ACRONYMS AND ABBREVIATIONS

CLU	Coffee Liquoring Unit
CQIP	Coffee Quality Improvement Program
CRD	Completely Randomized Design
EAFCA	East African Fine Coffee Association
ECX	Ethiopian Commodity Exchange
EIAR	Ethiopian Institute of Agricultural Research
FTLO	Fair Trade Labeling Organization
FAO	Food and Agriculture Organization
GDP	Gross domestic product
g	gram
IAR	Institute of Agricultural Research
ICO	International Coffee Organization
IMF	International Monetary Fund
ISO	International Standard Organization
ITC	International Trade Center
Kg/m^2	Kilogram per meter square
JARC	Jimma Agricultural Research Center
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
JZADO	Jimma Zone Agriculture Development Office
LCPDE	Limmu Coffee Plantation Development Enterprise
MoA	Ministry of Agriculture
OCFCU	Oromia Coffee Farmers Cooperative Union
OTA	Ochratoxin A
‘Q’	Quality
SCAA	Specialty Coffee Association of America
U.S.	United States
UG	Under Grade

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EFFECT OF SUN DRYING METHODS AND LAYER THICKNESS ON QUALITY OF SELECTED UNWASHED ARABICA COFFEE VARIETIES IN JIMMA ZONE

ABSTRACT

*Coffee is the most important crop in the national economy of Ethiopia and continues to be still the leading export commodity. Despite the economic importance, productivity and quality of the crop is very low, primarily because of poor field management and post harvest handling practices. Improper post harvest processing techniques largely contribute to the decline in coffee quality and are influenced by several factors, of which post-harvest on-farm processing is the major one. Though Jimma is well known as the center of coffee diversity and high production potential area in Ethiopia, the quality of its coffee does not have deliverable grade status and seeks further improvement. This calls for intensive efforts to identify post-harvest practices and drying techniques and to come up with technical recommendations that enhance coffee quality. Therefore, this experiment was carried out to determine the effects of altitude, sun drying methods, variety and cherry drying layer thickness on quality of coffee under different location of Jimma zone. Accordingly, on-farm processing experiments were conducted in Jimma zone at state owned coffee farms under Limmu Coffee Plantation Development Enterprise (LCPDE) from September up to December, 2010. The experiment was laid out in 3x3x3x4 Split-Split-Split-plot design arranged in CRD with three replications. The four factors comprise three locations: Gomma-1, Gomma-2 and Kossa coffee farm sites assigned to the main plots; three drying materials: bricks floor, raised beds with bamboo mats and raised beds with mesh wires assigned to the sub-plots. Three coffee varieties: 744, 74110 and 744+74110 assigned to sub- sub-plots and four levels of cherry layer thicknesses: 20; 30; 40kg/m^2 (uniformly spread) and the farmers' conventional practices (40kg/m^2) as sub- sub-sub plot treatments. The treatment combinations comprised 108 units replicated at each location, providing a total number of 324 sample sizes. Combined analysis was applied after homogeneity test to estimate the average response suitable for particular location. Similarly, cupping was done by three cuppers at (*OCFCU*) coffee cupping laboratory in March, 2011. The data were computed by using list significant differences (LSD) procedures of SAS version 9.2. As a result, the interaction effects were highly significant (P≤0.01) for hundred bean weight and total coffee quality and significant variations were observed (P≤0.05) for drying period, total raw quality, total cup quality and coffee grades. The finding revealed that; depending on the agro-ecologies, processing coffee on raised beds using appropriate layer thickness loads of 20 to 30kg/m^2 and 40kg/m^2 at low/mid and at high altitudes produce quality coffee identified as total quality scores ranging 80-89.99 points and can attain "Specialty Grade 1 and 2" classification profiled under grade 2.While, the conventional systems produce low quality coffee identified as commercial grade classifications profiled under grade 3 to 6. Hence, using appropriate dry processing approaches, it is possible to produce specialty coffee at different agro-ecologies. However, further study including stirring frequency, identification of the actual differences in quality on distinctively processed coffee and action research to improve the processing practices should be conducted to give concrete recommendations.*

Keywords*: Effect, sun-drying, layer thickness, on-farm processing, total quality and specialty coffee*

1. INTRODUCTION

Coffee is global commodity and a major foreign exchange earner in many developing countries (Tadesse and Feyera, 2008). Ethiopia is the original home of *Coffea arabica L*, and thus, possesses the largest diversity in coffee genetic resources and Africa's leading producer and exporter of Arabica coffee (Mayne *et al*., 2002; Girma, 2003). The country largely depends on coffee as a major earner of the economy. It has accounted on average for about 5% of Gross Domestic Product (GDP), 10% of total agricultural production and 41% of total export earnings for the past few years (Worako *et al*., 2008). Over 25% of the populations of Ethiopia, representing 15 million people, are dependent on coffee for their livelihoods. This includes eight million people directly involved in coffee cultivation and seven million in the processing, trading, transport, and financial sector (Oxfam,2002; IMF,2006) with an export sector valued at $525million (Jean-Pierre *et al.*, 2008).

Coffee is produced in many places of Ethiopia that range in altitude from 550 to 2750 meters above sea level. The bulk of *Coffea arabica* is produced in the eastern, southern and western parts of Ethiopia, with altitudes ranging from 1300 to 1800 meters above sea level (m.a.s.l.) (Aklilu and Ludi, 2010). Gale (2009) estimated that from the total Ethiopian coffee production about 10% is obtained from forest coffee systems, 35% from semi-forest coffee systems, 35% from garden coffee systems and 20% from plantations. The total area coverage of coffee is estimated to be around 800,000 hectare which accounts for 3.14% of the country's total area under crop cultivation of which about 95% is produced by 1.2 million small scale farmers. At present, Ethiopia exports 170,000 tons and the domestic consumption is estimated to be about 50% of the total production (Esayas, 2009; Aklilu and Ludi, 2010). The annual coffee production is normally in the range of 300,000-330,000 tones, which is about 600 kg/ha. Although Ethiopia is known to be the first in Africa in terms of coffee production and eighth major supplier of the global market, its share accounts for only 3% of the global coffee trade. This calls for transition to more dynamic and innovative approaches that can adapt more easily to changing market signals (Baumann, 2005). According to ICO (2008), annual production of Ethiopia is on an increasing trend from 3,693,000 bags in 2002 to 5,733,000 bags in 2007.

Despite the importance of the crop, low yield due to poor agronomic practices and lack of appropriate varieties recommended for different agro-ecologies and poor post harvest management activities are the major problems threatening Ethiopian coffee sector. Furthermore, numerous factors are affecting coffee quality. The post harvest processing techniques largely contribute to the decline in coffee quality (Bayetta *et al.*, 1998; Behailu *et al*., 2008). The quality of Ethiopian coffee is determined by two main factors namely the geographic origin and the post-harvest processing techniques (Petit, 2007). Methods of coffee processing in Ethiopia are sun-drying of unpulped cherries and wet processing, of which sun drying is preferred by farmers. Unwashed coffees are mainly from Harar, Jimma, Bale, Wellega and Illubabor (Surendra and Ann, 2002; Endale, 2007). From the total coffee production of Ethiopia, the highest proportion accounts for dry processed coffee. Washed coffee accounts for 29 % while sun-dried accounts for 71% of the processed coffee (Musebe *et al*., 2007). Similarly, Ethiopia exports about 65-70 % natural or sun-dried coffee and 30-35 % wet-processed coffee (Russell, 2008; Selamta, 2010).

Quality is the most important parameter in the world coffee trade. It is estimated that the quality of coffee is determined by 40% in the field, 40% at post-harvest primary processing and 20% at secondary processing and handling including storage. This underscores the importance of primary processing in enhancing the quality and value of coffee (Musebe *et al*., 2007). As Ethiopian coffee is produced in small quantities by many small-scale farmers, it is difficult to manage quality and significant quality losses occur at various stages. Further quality losses also occur due to poor post-harvest on-farm processing, including poor storage infrastructure and contamination with other products. The bulk of Ethiopian coffee exports are low grade coffee, 3rd or 4th quality grade classification (Desse, 2008). It requires maintenance of a consistent and relatively high quality set of coffee which would be priced with a constant differential in the New York market. Thus, despite its status as a relatively important producing country, Ethiopia is unique in not having acquired this status, in contrast to most producing countries (Reporter, 2010).

Jimma zone is one of the major coffee producing areas with about 105,140 hectares of land covered with coffee. Though Jimma is well known as the center of coffee diversity and high production potential, the quality of its coffee is not to the required level and does not have deliverable grade status on the international coffee market (Desse, 2008). According to Jimma Zone Agricultural Office (JZAO), the total annual coffee produced in 2009/10 was 36,408.69 tons; about 30.45 % is washed and 69.55 % is unwashed coffee (Unpublished data,2010) of which sun- dried coffee accounts for about 76% of the total coffee marketed in Jimma zone (Aklilu and Ludi, 2010). Desse (2008) reported that more than 60 % of dry processed coffee was classified into grade 3 as compared to 80 % of wet processed coffee which were classified in to grade 2 and grade 3. Even though, Jimma contributes 27 % of the country's export coffee and 43% export share of Oromia region. Jimma 5 is the least priced coffee when compared with the other origins and preparations as a result of its mediocre quality due to choice of inappropriate processing.

Anwar (2010) reported that the pre-harvest and harvest activities of coffee in Jimma zone are in progress but the post harvest operations mainly the primary processing activities of natural drying methods are still not practiced in appropriate manner to maintain the intrinsic quality of coffee. The problem of post-harvest processing and handling as one of the main contributing factor in the area resulted in poor quality. Farmers dry their coffee using different approaches. About 48% of producers spread their coffee on the ground, about 49.5% dry on raised drying beds using either bamboo mats or wire meshes and only 2.5% dry on cemented/bricks floors (Musebe *et al*., 2007). Further more, farmers' cultural practices on post-harvest operations, such as mixed drying and undesirable layer thickness of coffee upon drying and heaping of coffee before drying favoured development of fungus and bacteria and cause quality deterioration.

So far, few research works have been conducted in the area of wet processing with regard to fermentation, drying depth and time of storage (Behailu *et al.*, 2008). However, post-harvest processing of unwashed coffee has not been well studied at field level. This calls for intensive efforts to identify post-harvest practices and sun-drying methods to come up with technical recommendations to enhance coffee quality. Although Ethiopia has favorable conditions for the production of fine quality coffee and different coffee types of Arabica coffee varieties representing the characteristics of big size (744) and small size (74110) beans are liked for their unique flavour and taste, the country has not benefited from the huge potential as it should do, mainly because of the traditional processing practices employed by producers ((Behailu *et al*, 2008 and CAB International, 2009). In view of the paramount importance of coffee to Ethiopia and to the world at large and the stringent demand for quality coffee in the competitive market, there is a pressing need for better processing and handling technique. Therefore, this experiment was carried out to determine optimum drying depth and appropriate dry processing methods of unwashed Arabica coffee in different agro-ecologies of Jimma area.

Objective:

To determine the effects of altitude, sun drying methods, variety and cherry drying layer thickness on quality of coffee under Jimma condition.

2. LITERATURE REVIEW

Coffee is the most important crop in the national economy of Ethiopia and continues to be still the leading export commodity. In recent years, different coffee producing countries have tremendously expanded their production and their export volume and providing good quality coffee is the only way and viable option to get in to world market and to remain competitive (Behailu *et al.,* 2008). The principal objective of producing coffee is to maintain the inherent desirable quality of the beans that leads to good beverage taste and consumer satisfaction, a product that eventually fetches higher income. Coffee processing is a critical operation undertaken with great care as quality could be enhanced or compromised in the course of processing (CAB International, 2009).The choice of processing method depends heavily on market considerations and is also often dictated by custom and practice of growing regions (ICO, 2010).

2.1. Coffee Processing

Since Arabica varieties of coffee ripen over a range of several months, harvesting must be selective and focused on only red, ripe fruit.Coffee is processed by two widely known methods; dry and wet methods. The methods of coffee processing in Ethiopia are sun-drying of un-pulped cherries and wet processing, of which sun-drying is preferred by farmers. Washed coffee accounts for 29 % while sun-dried accounts for 71% of all processed coffee (Musebe *et al*., 2007). Ethiopia exports 65-70 % natural or sun-dried coffee and 30-35 % wet-processed coffee (Russell, 2008; Selamta, 2010). Sun dried coffee accounts for about 76% of the total coffee marketed in Jimma zone. Although washed coffee fetches relatively good prices for producer farmers, its production is limited due to lack of processing facilities, labor shortage with regard to picking up the red cherries, and fluctuating (low) prices. Hence, the pattern over the past years in the area indicates a tendency towards the production of sun dried coffee rather than washed coffee (Aklilu and Ludi, 2010). The natural coffee processing can produce high quality coffee and create a highly preferred coffee compared to full wash and wet-hulled indicating that processing does have an identifiable influence on cup taste (Antonym and Surip, 2010).Processing style has a large influence on the quality and flavour of coffee (Drinnan, 2007).From different processing techniques, the actual difference in quality of technologically and distinctively produced coffee has not yet known (Subedi, 2010).

2.1.1. Wet-processing

The wet processing method requires the use of specific equipment and substantial quantities of water. In the washed coffee processing, the ripe fruit is squeezed during pulping, which is the key operation and different from the dry process in which the soft pulpy part of the cherry together with the skin is 'torn off' as soon as possible (Clark, 1985).When properly done, the qualities of the coffee bean are better preserved, producing a green coffee which is homogeneous and has few defective beans. Wet processed Arabica is aromatic with fine acidity and some astringency, while dry processed Arabica is less aromatic but with greater body. In general, washed coffee carefully prepared and handled, is clean in flavour and free from undesirable elements (Clifford, 1985).

2.1.2. Dry processing

The dry processing method is the standard method of processing Arabica coffee and consists of two stages: drying of the fruit cherries; removal of the dried coverings in a single mechanical operation (Coste, 1993; News Release, 2008). Sun drying is the preferred drying technique and needs to be supervised very carefully as site and climate conditions strongly influence coffee quality (GTZ, 2002). Coffee processing regardless of the degree of the techniques employed, and quality can easily be lost by inappropriate drying (ICO, 2010). Dry processing is the simplest to use or relatively more straightforward and usually more economical. However, it produces coffee of inferior quality (Russell, 2008; Selamta, 2010). Variable quality has been a criticism of dry processed coffee and some of the faults have been attributed to poor drying in the field after harvest leading to moulds and fungal growth tainting the flavour (Drinnan, 2007a). Because the preparation is very poor, dry processed coffee has low aroma, flavour and acidity (Mawardi, 2005). Improved sun-drying wherein coffee is dried on raised drying beds is advocated for improved quality (Musebe *et al*., 2007).Similarly, Appropedia (2010) reported that in the dry processing system a good quality finished product can only be obtained through the application of good practices and proper management. Similarly, Negussie et al., (2009) pointed out that properly processed coffee is free from off- flavour and very few defective beans. All coffees produced can attain higher grades if properly processed.

Dry processing is important from safety perspective as well as quality aspects of the finished coffee (Gianni, 2004). The drying operation is the most important stage of the process, since it affects the final quality of the green coffee (FAO, 2002).Although it is a simpler process compared to wet processing, a good quality finished dry processed product can only be obtained through the application of appropriate and scientifically tested practices and proper management (Appropedia, 2010).In this context, Endale (2008) reported that coffee with a better attention/management turn out to have a better flavour. According to CAB International (2009) dry processed coffee generally has inferior appearance as compared with washed coffee however the quality can be considerably improved through better drying practices and produce high quality coffee as that of wet processed coffee. Bacon (2005) also reported that dry processed (natural) coffees have a full body and natural sweetness of the beans. Natural processing of coffee is often viewed as inferior form of processing, perhaps because of its relatively low technology which is often inconsistent due to poor quality control by smallholders. Therefore, if consistent quality control is applied to every stages of dry processing the resulting coffee is highly preferred by the specialty coffee industry (Antonym and Surip, 2010).

2.2. Processing Factors Affecting Coffee Quality

2.2.1. Drying methods

Sun drying can be an economical and effective method, producing high quality coffee under good ambient conditions (ICO, 2010). In this process, the product is spread on surfaces such as cement or brick terraces, bamboo and sisal mats, raised tables covered with wire mesh**.** The structure and location of these facilities has a great influence on their performance, when drying coffee on surfaces given the potential problems associated with drying and its negative image (FAO, 2010a).While drying on bricks floor in contact with soil becomes dirty and blotchy resulting into dull aroma and earthy flavour in coffee beverage (Subedi,2010) .Similarly, drying coffee on terraces, the development of micro organisms on the surface of cherries and increase in respiration rate and temperature are factors that accelerate the fermentation process to facilitate deterioration (Silvano, 2004). Drying tables covered with mesh or mats are used where frequent showers can be expected during the harvesting period because tables present two surfaces for moisture loss. The open lower surface prevents condensation and allows drying to continue slowly (FAO, 2010a). Drinnan (2007b) reported that processing style has a large influence on the quality and flavour of coffee.

Processing with samples of similar ripeness, creates significant differences in the quality of beans (Bytof *et al.*, 2000).The size of the individual compartments in the dryer allowing for a thickness of one bean for the initial drying, maximize exposure to the sun (Selmar *et al.*, 2006). At night fully wet coffee should not be covered, to avoid condensation of the water to be lost. After one day of drying for parchment and three days for cherry coffee, it can be heaped and covered at night. Under rainy weather dry or partially dried coffee must be protected from re-wetting. It is recommended that one should not mix different types of coffee nor different days of harvest, using a specific identification for each one of them to avoid mistakes (FAO, 2006). Similarly to facilitate rain water drainage, the drying terrace should be built with steepness in the range of 0.5 to 1.5% with drains located in the lower part of the terrace (ICO, 2010). The drying operation is the most important stage of the process, since it affects the final quality of the green coffee (Hicks, 2002). The dryness of coffee is important not only to prevent fungal growth, but also to maximize value, since green coffee is sold on a weight basis (Selmar *et al*., 2006). Degree of dryness is tested with two methods: dental and digital. The digital method relied on a digital grain moisture meter. This meter has a range of 10 to 24% moisture content, reads to 0.1% moisture, with an accuracy of +/- 1% (Reh *et al*., 2006).

In Ethiopia, farmers dry their coffee using different approaches. About 48% spread their coffee on the ground, 49.5% dry on raised drying beds and 2.5% dry on cemented /bricks floors (Musebe *et al*., 2007). The use of drying beds, as opposed to traditional ground drying, allows air to circulate around the beans for even drying and a richer, more flavorful product (Selmar *et al.*, 2006). In processing sun-dried coffee; the cherry is dried from a moisture content of about 65% to 12%. The cherries are dried on beds constructed from chicken wire and fixed on wooden frames raised about 80 cm above the ground. A metal mesh base allowed airflow to help speed the drying process. The result is cleaner cupping specialty naturals with beans that have a more consistent appearance. In the cup, natural coffees exhibit heavier body and flavor profiles; it was possible to enter into the specialty market (News Release, 2008**).**

Drying tables covered in mesh or mat is used where frequent showers can be expected during the harvesting period because this system simplifies protection of the crop from re-wetting (ICO, 2010).According to Anwar (2010) dry processing method is affected by processing approaches. Coffee drying on raised beds covered with mesh wire and bamboo mats has better quality. However, conventional way of coffee preparation at Gomma woreda resulted in lower grade (grade 4). Where as, in Manna Woreda, relatively good grade was obtained and local way of processing accounted for 25% of grade 2 and 75% of grade 3.Dry processed coffee on mesh wire took much longer time and coffee drying on bamboo and cement floor dried earlier (Beza,2010). The sun dried coffee variety dried on raised beds with mesh wire following appropriate management had a good physical and over all cup quality with a value of 84.25 points, as far as their total physical and cup quality are concerned (Mekonnen, 2009).According to Beza, (2010) dry processed variety 74110 dried on mesh wire, and bamboo was profiled under grade 2 at JARC. Moreover, dry processed variety 7440 and 75227 dried on mesh wire, jute mesh, palm leaves mat and bamboo were profiled under grade 3 at Jimma.

2.2.2. Layer thickness

The amount of cherries required to dry coffee varies with the surface on which it is dried. Drying cherries under the conditions of the load of dryer 10 kg/m^2 should be recommended but the investment is high and probably not profitable. The choice is therefore between 30 kg/m^2 and 50 kg/m^2 loads. The shape of drying curve for 50 kg/m^2 load might favor mould growth and thus, it is preferable to choose a load of 30 kg/m^2 (Duris and Bonnot, 2004).Similarly, drying coffee only in thin layers, 3 to 5 cm in deep, which is equivalent to 25 to 35 kg/m^2 of fresh parchment or cherry coffee is also being practiced (FAO, 2010a).According to Coste (1993), the thickness of layer of fruit must be not exceeding 5 to 6 cm which is equivalent to about 40kg of fresh fruits per square meter as there is a risk of: mould development, seed germination and black bean formation. FAO (2010a) indicated that just under very favorable conditions such as low air humidity, good air circulation and sun intensity, or in usually dry regions, thicker layers can be used. On the other hand; Solomon and Behailu (2006), mentioned that drying depths of washed coffee were identified to determine the optimum depth that correlates with above average or acceptable cup quality characteristics of Arabica coffee under Jimma condition. Coffee dried at depths 2, 3 and 4 cm attained the highest cup quality grades while the other depth (5 cm) was associated with lower quality standards. As drying depth increased, there was a linear increase in drying time and vice versa. Therefore, a depth 2 to 4 cm is recommended to dry parchment coffee. According to Gianni (2004) thickness of cherries must not exceed 4cm as the maximum depth (5 cm) was found to prolong the drying time and lower the general quality characteristics. Higher heaps show delay in drying while sparsely spread once result admixture of under dried and over dried beans (ICO, 2010). Consequently, the coffee is heaped unevenly yielding inferior cup taste or quality (Solomon and Behailu, 2006). Ripe fruit dry at different rates and subject to over-fermentation are believed to compromise the quality of dry processed coffee (Drinnan, 2007).

2.2.3. Drying period

The required length of the drying period for coffee cherries varies from 3 to 4 weeks. However, the cherry would be fully dry after 12-15 days under bright weather conditions (Bhawan and East Arjun, 2006). On the other hand, Gianni (2004) reported that the total drying time varies between 10-20 days depending on the different regions and climate conditions prevailing during the drying period. Recent report also depict that for a given thickness layer, the length of the drying process depends mainly on weather conditions and degree of initial moisture content and size of the berries (FAO, 2010a).Time required achieving dryness of three weeks for cherry, and two weeks for parchment coffee, is also tied to a loading rate of 30kg/m^2 (ICO, 2010). Coffee beans may require more days to dry depending on the methods of drying and the density at which the beans are dried (Lower *et al*., 2007).

One of the factors that influence the rate of sun drying is frequency of stirring the coffee. Some farmers stir the coffee, but most do not. Eventually, the coffee fruit rots, gets covered with a white mould, and as time passes, dries out (Daniels, 2009). Stirring the coffee is a problem in thick layers and allowances for redistribution of moisture in the coffee bed must be made. During operation a moisture gradient in parallel with the temperature gradient will be established such that coffee near the bottom is over-dried and that near to the outlet, under dried (ICO, 2010).Frequent raking such as turning frequency in which the optimum seems to be 4 stirrings per day and covering during night and when it rains (Duris and Bonnot, 2004) is necessary during the earlier wet stage to stop mould proliferating. Dry coffee is taken in to store when it attains optimum moisture content (below 12%) (Clarke and Macrae, 1989b).

2.3. Coffee Quality

Quality is defined by ISO as "the ability of a set of inherent characteristics of a product, to fulfill requirement of customers and other interested parties". A more practical definition is "the ability of a product to satisfy consumer expectations" (ISO, 2000). Quality is the most important parameter in the world coffee trade and due to the increasing competition in the world market, producing high quality coffee has become so crucial. Coffee without physical and sensorial defects and with a good physical appearance is normally required (Solomon and Behailu, 2006). Quality coffee is highly associated with consumers' satisfaction, a product that eventually fetches higher income and is an important aspect in today's competitive market (CAB International, 2009). Coffee from known geographical origin that has value premium above commercial grade due to its high quality in the cup and to particular attributes that it posses is classified as specialty coffee (Reuters, 2009). More importantly, estimates of the potential to increase the volume of specialty coffee suggest that up to two third of Ethiopian coffee can be qualified as specialty through increased washed coffee stations and quality improvement of dry processed coffee (ECX, 2010).

Coffee quality is affected by many factors. The most important factors that dictate coffee quality are harvest and post-harvest handling, environment and genotype. These major factors control coffee quality together. It is estimated that the quality of coffee is determined by the conditions (40%) in the field (40%) post-harvest primary processing, and (20%) secondary /export processing and handling including storage. This underscores the importance of primary processing in enhancing the quality and value of coffee (Musebe *et al*., 2007).

2.3.1. Environmental and Genetic Factors Affecting Coffee Quality

Factors affecting quality are edapho-climatic conditions, coffee berry at harvest bean processing genetic properties and agricultural practices (Harding *et al*., 1987). Coffee quality involves several components. These traits are subject to different sources of variation. Some of them are exclusively dependent on the harvest and post harvest whereas others will depend on physiological factors of the coffee plant (Bertrand *et al*., 2004). Elevation is a very important factor to produce high quality coffee (FAO, 2010b). Yigzaw (2005) stated that provided other factors are kept constant, better quality coffee can be produced at higher altitudes, while lowland coffees are somewhat bland, with considerable body. Beverage quality is therefore partly determined by environmental factors (Avelino *et al*., 2005).

Similarly, bean size is an important feature for coffee quality. Van der Vossen et al. (1985) observed variation for cup quality characters among varieties and crosses of Arabica coffee. For instance; coffee variety SL28 has big sized beans and excellent cup quality, while Caturra and Rumen Sudan are characterized by small sized beans and lower cup quality. Bean size and dry weight increased as elevation was higher and as shoot age was younger. The ultimate size of coffee bean is determined by the amount of rainfall during the rapid expansion period (Tesfaye *et al.,* 2008). Generally, there is a positive relationship between bean size and coffee quality. Although partly genetic, the size can be modified by ecological conditions and crop husbandry (De Sousa and Roberto, 2010). The species of coffee grown in different countries may also influence the preferred processing technique (Drinnan, 2007a).

Ecological conditions considerably affect the growth of coffee trees. This effect is ultimately reflected in the coffee quality attributes. For example, coffee grown at low altitudes is generally inferior in coffee quality (De Sousa and Roberto, 2010).The production of good quality coffee beans in specific areas characterized by their climatic conditions clearly shows that the climate is an important factor in determining the quality of the coffee beverage (Emerson *et al*., 2005).

Climate, altitudes, 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 (Leroy *et al*., 2006). The influence of soil is one of the most influential aspects to coffee plants. Most of the best quality coffee is growing in the high mountain region linking up with the topography and annual precipitation (Borovikovskaya, 2007). In addition, it has been found that beans produced at low altitude (hot and humid environment) have a negative effect on the flavour and the structure of the fruits due to accelerated maturation (Wintgens, 2004). Roche (1995) assessed the association of cup quality and green bean physical characters using 15 *C. arabica* cultivars and reported that unlike the popular belief, bean size was not a good indicator of cup quality when comparing cultivars from a single production area.

2.3.1.1. Effects of tree physiology on quality

Coffee physiology, plant age, and period of picking all interact to produce the final characteristics of the product. Indeed, it was found that tree age, location of the fruits within the tree, and fruit-to-leaf ratio had a strong influence on the chemical content of green beans (Vaast *et al*., 2006). Maturation also has a strong influence on coffee quality (Leroy *et al*., 2006). Clark and Macrae (1989a) summarized that coffee quality is a complex trait that relies on multiple factors. The choice of cultivar, variety or species of coffee is an important factor in coffee quality.

According to Subedi (2010), bean size play an important role for roasted whole coffee beans because many consumers associate bean size with quality, however, large beans do not necessarily mean better than smaller one. The size and shape of the beans differ depending upon the variety, environmental conditions and management practices. On average, beans are 10 mm long, 6-7mm wide, 3-4mm thick and weigh between 0.15 and 0.20 g. Furthermore, Arabica varieties were diverse in respect of average hundred bean weight with values ranging between 18.2 g and 9.2 g (Wintegens, 2004). The bean weight of coffee accessions harvested is highly influenced by both coffee genotype and processing methods treatments (Mekonnen, 2009). Agwanda et al. (2003) reported that unlike the popular belief, bean size was not a good indicator of cup quality. It is clear that the relationship between size and cup quality is weak. This finding is at odds with the commonly held market belief that larger bean sizes are superior in quality, irrespective of cultivar. It is more likely that bean size would be a useful indicator of cup quality within a single cultivar as it relates to horticultural practices and environmental conditions during a given growing season (Roche, 1995).

2.3.1.2. Genetic variation for quality

The genus *Coffea* includes more than one hundred different species among which a large variation in terms of chemical composition is observed. Coffee produced from *C. arabica* L. is known to have a good quality (Clifford and Wilson, 1985). The presence of large inherent differences among genotypes for bean and cup quality attributes (Walyaro, 1983). Yigzawu (2005) reported that inherent variability that exists in the respective varieties, suggests suitability of acidity and body as selection criteria for the genetic improvement of overall liquor quality and there was a reported variation in the body among genotypes of *Coffea arabica*. The presence of genetic variability among Ethiopian coffee selections for green bean physical characteristics, cup quality, green bean caffeine, chlorogenic acids, and sucrose and trigonelline. Similarly, Van der Vossen (1985) observed significant differences among different Arabica coffee cultivars for quality attributes. Furthermore, Behailu et al. (2008) reported that based on the assessment the Coffee Liquoring Unit (CLU) of Ethiopia made from 1996 to 2004 quality evaluation of the 23 pure line and 3 hybrid varieties showed that all had commercially acceptable quality.

2.3.2. Effects of harvesting and post-harvest operations on quality

Harvesting is one of the important stages that have considerable impact on quality. Cherries of good quality can produce good cup quality provided ripe fruits are harvested, properly processed and dried. Conversely, good coffee cannot be made from poorly harvested coffee cherries. Only large and fully ripe berries from disease-free, pest-free and high-yielding trees should be selected (Wintgens, 2004). In practice, there are considerations that arise requiring the drying rate to be moderated purely from the aspect of preventing mould growth and the control parameters should be designed to maximize drying rate, and eliminate inappropriate intermixing and re-wetting

(ICO, 2010).Among the different unit operations, drying is the most important stage of the processing, since it affects the final quality of the green coffee. Depending on the post harvest process, strong consequences on coffee quality can be observed (Leroy *et al*., 2006).

2.4. Coffee Quality Characteristics

Quality coffee means better market access which in turn implies competitive prices and better income (EAFCA, 2009). Leroy et al. (2006) mentioned the important quality characteristics in order to illustrate the problems and constraints one faces to improve coffee quality. Three of them, i.e. moisture content, physical and organoleptic qualities are used all along the production chain. An organoleptic quality, i.e. "health quality" is a characteristic more and more taken into account by the consumers.

2.4.1. Physical and organoleptic qualities

The quality of the coffee drink is directly related to various physical and chemical constituents that are responsible for the appearance of roasted bean and characteristics taste and aroma of the drink (Ross and Nogueira, 2001). In general, dry processed coffee produces a beverage with a strong aroma, moderate acidity, strong body and natural wetness (Prodolliet**,** 2004).

Grading systems in coffee reveal a high diversity of classification systems is applied and the use of the "expert cupper" is the norm. There is no a unique and universal system applied world-wide for the quality control of green coffee. Procedures are mostly geared to facilitate the trading of the commodity and sensory quality and in most cases described by "cuppers" or "liquorers" using personal opinion and tasting experience accumulated over the years (Alejandro and Morales, 2002).

2.4.1.1. Moisture content

Beginning at the time of harvest, moisture is a key determinant of the maturity of the berry for harvest. This maturity has a continuing influence on the quality of the coffee at each of the next steps. According to Gtz (2002), during drying cherries, the moisture trapped inside the bean slowly migrates to the outside and is absorbed by the warm air. Thus, moisture evaporates from the surface of beans causing moisture from the inside of the bean to travel to the surface. It is a principal economic factor due to weight loss of the green beans during storage and roasting. Drying brings the moisture content of the beans from above 50% down to 10-12% for well-dried beans. This is most often accomplished with solar energy (Selmar *et al.*, 2006). Moisture in coffee beans is frequently a last minute item of concern. However, it is a significant factor in the quality and cost of coffee (Robin, 2009). Quality deterioration occurs due to an increase of moisture content of the bean, the spoiling of the raw appearance of the bean by loss of color due to fading or tainting, or to the introduction of unpleasant flavours, by infestation of storage insects or by infection with moulds or bacteria (Behailu *et al*., 2008).

Green coffee behaves very differently at high or low moisture content. Although, there is no exact standard defining the ideal moisture content, it is generally recognized that it should range between 8.0-12.5% (Prodollit *et al.*, 2004). According to Leroy *et al*. (2006) moisture is an important attribute and indicator of quality. The moisture content influences the way coffee roasts and the loss of weight during roasting.

2.4.1.2. Bean physical quality

The International Coffee Organization implemented a Coffee Quality Improvement Program (CQIP) with recommendation to exporting countries (ICO, 2002).It has also established a standard (ISO, 10470) that describes defects as: foreign material of non coffee origin; foreign materials of non bean origin, such as pieces of parchment or husks; abnormal beans for shape regularity/ integrity; abnormal beans for visual appearance, such as black beans; abnormal beans for taste of the cup after proper roasting and brewing. It is clear that defects are one of the most important criteria of the evaluation of green coffee, as their presence can greatly alter the final cup quality by generating off flavours. According to ISO (2004b), in the new version, defects are manually separated according to their type. The number of visually defective beans plays a huge role in how the coffee is graded. Defects may include black beans, mottled beans, broken beans, and crystallized beans; each of these indicates a specific problem with the processing that will also be apparent in the next step, the cupping of the samples (Farah *et al.*, 2006).

Coffee quality is evaluated through size of beans, their lack of physical defects and the quality of the beverage. The classification of coffee through physical analysis is a good tool for quality control **(**Bertrand *et al*., 2004). The quality of flavoured coffees is assessed at various points throughout the manufacturing process. Before roasting, beans which do not meet standards for color or sizes are removed .Coffee is graded by size, shape, odor, density and color. For small-scale units this is best done by hand (Russell, 2008; FAO, 2010b). The internationally acceptable screen unit is $1/64^{o}$ of an inch. For example, beans of screen 18 refer to those that are retained by a sieve with aperture (holes) of diameter 18/64 of an inch (ISO, 2000; EAFCA, 2009).

In *Sensu Stricto*, grade indicators are used to describe the size of the bean and screening is done to make size assessment. This is conducted manually by taking 350 g of green sample from the bulk sample. Screen size used to identify coffee bean size (>85% above screen size of 14 units) is possible to draw the raw quality. Various screen size from screen number 10-20 and slotted screen was used to identify the different coffee bean size, so that it is possible to draw the raw quality in relation with largeness, boldness, medium and small bean size. Finally raw and cup evaluations are considered for assessing of coffee quality as per the standard procedures (ISO, 2000). Based on standard conditions; to count primary and secondary defects a 350g sample green coffee is needed for grading to Specialty Coffee Association of America (SCAA) standards and moisture content needed to be 10-12% (11.5% is optimum) (SCAA, 2009). Grade is generally used to indicate coffee bean size, which is associated with coffee quality. While there are many exceptions, coffee beans grown at higher elevations tend to be denser, larger, and have better flavour (FAO, 2010). Desse (2008) reported that although the inherent flavor of Jimma coffee is pleasantly winy, some of the common cup defects are earthy, musty with secondary cup defects of taints in the liquor, which are mainly due to post harvest management problems. On the other hand, the foxy beans observed in locally prepared dry coffee was probably due to in appropriate high drying temperature, prolonged drying period extended over a long time and coffee dried on bricks floor (CLU, 2007).

2.4.1.3. Organoleptic quality

Assessment of coffee organoleptic quality is an extremely demanding exercise. 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 (ICO, 2004). The assessment of coffee organoleptic quality is a difficult task. The smell of the ground roasted coffee before water is added is sometimes called fragrance, then, one can smell the aroma, evaluate the body and perceive taste and flavors. Organoleptic quality measurement relies overall on sensory evaluation (Leroy *et al*., 2006). Expert assessors can describe a profile following a complex procedure which uses some specific descriptors. There are some existing glossaries (ITC, 2002; ICO, 2004), but ISO would soon elaborate a list of descriptors specific for coffee and expert assessors have to be trained to use the vocabulary (Prodolliet, 2004). Quality test as an important parameter as cup quality is the characteristics of most interest to all coffee buyers (Behailu *et al*., 2008). Sensory characteristics include elements like aroma, body, acidity, flavor and aftertaste. Professional tasters follow a protocol for the evaluation of these characteristics. Well-trained tasters are able to separate personal preference from the sensory evaluation on the cupping table and this is an essential element in determining the potential of a coffee to satisfy needs of roasters and consumers (Parker, 2010*)*.

Three professional tasters carry out sensorial assessment of the coffee samples. An overall criterion, named global quality, is used to classify the quality of each beverage. This criterion includes the aroma, body, acidity and bitterness and is based on a hedonic scale from 0 (absence of the criterion) to 5 (presence). Similarly among liquorers in ranking various cup quality characteristics of the cultivar, indicating that any one panel could be relied on selection for cup quality. Thus, coffee cupping is a technique used by cuppers to evaluate the flavor profile of a coffee (Braz, 2005). The ISO 6668 specifies the standard for sampling, roasting and grinding conditions and the preparation of the brew. There is a recently created new working group to elaborate a vocabulary for the sensory evaluation of coffee products accounting existing and published glossaries (ICO, 2004; Pridolliet, 2004).

2.4.1.4. 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 (Leroy *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 has been shown to cause kidney damage and tumors in test animals. It is classified as possibly carcinogenic to humans (Sibanda, 2006).

In terms of chemical compounds present in coffee beans, several of them are known to have consequences on health. The one chemical component that has received the most scientific scrutiny is caffeine. Most consumers look for its stimulating effect on brain activity. Despite its positive effect on alertness, caffeine also has some possible implications in diseases like hyper cholesterol and cancers. To summarize, despite the knowledge acquired on a few components in terms of consequences on health, very little is known of the other constituents that make up 98 % of roasted coffee beans (Leroy *et al.*, 2006).

2.5. Coffee Quality Assurance

Quality assurance starts in the coffee field, where good agricultural and transport practices are essential to develop and preserved the natural quality of the green beans up to the coffee processor's door. The quality of a good cup of coffee is the result of a quality assurance program implemented by all the key players of the coffee production to consumer chain (Prodolliet, 2004). Quality as it is defined by ISO (2000) and Dessie et al. (2008), in its more practical definition, can be the ability of a product to satisfy consumer's expectation. They mainly include: good sensory characteristics (e.g. aroma, flavor, body, acidity); Absence of off-flavours (e.g. moody, earthy, fermented, and chemical); Safety (absence of contaminants, like pesticides, mycotoxins) and environmental aspect (e.g. organic product). Not all these quality characteristics are a matter of chance. They are the result of planned and systematic activities, prevented measures and precautions taken to ensure that the quality of coffee attained and maintained day after day (Prodolliet, 2004).

2.5.1. Green coffee

The International Organization for Standardization (ISO) issued in 2004 guidelines to be used to describe green coffee for sale and purchase (ISO, 2004a). The numbers of full defects are calculated on a basis of 350 g of green coffee sample. A full defect can be a category 1 (primary) or a category 2 (secondary) defect. A full defect is composed of one or more single defects depending on the impact each one has on the cup (SCAA, 2009).The ISO 10470 standards defines defects as "anything divergent from regular nicked sound green beans expected in a coffee lot. These are the most important criterion of evaluation of green coffee, as their presences alter the final cup quality by generating off -flavours" (Wintgens, 2004).

2.5.2. Coffee roasting

Roasting coffee transforms the chemical and physical properties of green coffee beans to roast coffee products. The roasting process is integral to producing a savory cup of coffee (Selamta, 2006). Green coffee must be roasted in order to give the final beverage- its unique sensory characteristics (ITC, 2002).Coffee can be roasted to various degrees, from very light to very dark. The degree of roast has direct impact on the sensory profile of the coffee, cup, which is a matter of consumer preference. It has also a great influence on the particle size distribution after grinding and, consequently, on the extractability of coffee. Therefore, the roasting process guarantees the consistent sensory quality of the finished produce (Prodolliet, 2004).

At the start of coffee roasting process, loosely bound water driven off and some shrinkage occurs, particularly with Arabica coffee. As evaporative cooling declines, so the bean temperature rises and an exothermic pyrolysis begins in the temperature ranges of 140–160 ^{0}C, and leads to the formation of the well known color, aroma and taste of roasted coffee product. The acceptable dry matter loss ranges from some 35 for a very pale roast to some 14 % for a very dark roast. The corresponding figures for total roasting loss (dry matter and water) are some 10 percent and 25 percent, respectively (Clifford, 1985). Uneven roast results in poor quality liquor, and dark roast enhances the body, while light roast emphasizes acidity (ITC, 2002). A large quantity of carbon dioxide is produced; its expansion generates internal pressure in the range from 5.5 to 8.0 atmospheres and accounts for the swelling of the bean by some 170–230 percent during commercial roast (Clifford, 1985). Brewing, 70% to 75% of the particles passing through a U.S. Standard size 20 mesh sieve. At least 5 cups from each sample should be prepared to evaluate sample uniformity (SCAA, 2009).

2.5.3. Sensory evaluation

Coffee quality may seem subjective, since it is related to how it tastes and smells, and personal preferences and sensitivities can vary widely. However, there is an increasing body of research that treats coffee quality as a quantifiable characteristic most strongly to aroma and perceived quality (Farah *et al.,* 2006). The tool commonly put to use is a panel of assessors (professional cup-tasters) who are trained, experienced tasters and have the vocabulary to describe the desirable and undesirable attributes of the beverage to describe organoleptic quality profile (Clifford and Wilson, 1985). According to ISO (2002) and Prodoliet (2004) sensory evaluation is certainly the most reliable way to assess the quality of the raw material. Cup quality, often referred as drinking quality or liquor quality, is an important attribute of coffee and acts as yardstick for price determination. For this, the assessment of sensory evaluation can be done organoleptically by panel of experienced coffee tasters (Van der Vossen, 1985). Owuor (1988) observed close similarity among liquorers in ranking various cup quality characteristics of the cultivar, indicating that any one panel could be relied on selection for cup quality. Thus, coffee cupping is a technique used by cuppers to evaluate the flavour profile of a coffee, to understand minor differences between growing regions, to evaluate coffee for consistence and defects to subsequently make buying decision and to crate coffee blend (EAFCA, 2008). This consists of six steps, to evaluate a coffee’s fragrance, aroma, nose, after taste, acidity and body (Lingle, 1986).

Cleanness is one of the grading factors of cup quality. It is well known that insoluble substances are formed during extraction (Clarke, 1985). These substances may eventually be carried over to the soluble coffee powder leading to an “unclear” coffee cup after reconstitution with hot water. Therefore, the purpose of measuring the cleanliness of the extract is to control the extraction and evaporation steps and to ensure clean coffee cup (Prodolliet, 2004). Cup cleanness indicates freeness of the coffee from defects (Cup cleanness 1-5 defects*)*.If there is problem during roasting, trained panelists will assess the organoleptic quality. Tasting will be carried out once the beverage cooled to drinkable temperature around 60^0c (ISO, 2000).

Evaluating the fragrances and tastes in a cup of coffee may seem subjective, and on some levels, it is. However, the entire process of cupping coffee focuses on eliminating conditions that may mask these tastes and using trained personnel with a talent for detecting and distinguishing subtle differences, and a strong memory for flavours. It has been used as an accepted method for quality evaluation in numerous studies (Silva *et al*., 2005). The aroma of a coffee is responsible for all flavour 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. Yet, the perception of aroma is dependent upon both the concentration of the compound and its odor threshold (EAFCA, 2008).

Acidity is an important sensory attribute of coffee brews influenced by several factors: coffee variety and processing methods, country of origin, roasting degree, water composition and coffee brewing method (Brollo *et al*., 2008). Acidity is a primary coffee taste sensation created as the acids in the coffee combines with the sugar to increase the overall sweetness of the coffee. It is taste sensation related to the presence of sweet-tasting compound which are created as acids in coffee, combine with sugars to increase the brews overall sweetness. Taste sensation experienced at the tip of the tongue (Willis, 2008). High acid coffees have a sharp, pleasing snappy flavour, not biting (EAFCA, 2008) and gives better quality and more intense aroma to the beverage (Clifford, 1985). 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, 1985).

Body is synonymous with mouth feel linked with density and viscosity of the brew (Petracco, 2000). However, there is no simple relationship between beverage viscosity measured instrumentally and body judged subjectively (Clifford, 1985). Similarly, flavour is the coffee's principal character, the mid-range notes, in between the first impression given by the coffee's first aroma and acidity to its final after taste. It indicates fragrance of the liquor either by direct inhaling of the vapors arising from the cup or nasal perception of the volatile substance evolving in the mouth (Petracco, 2000). Indeed, the flavour obtained in a coffee cup is the result of multiple aromatic compounds present and more than 800 in the roasted coffee (Bertrand *et al*., 2004). In addition, based on correlation, repeatability and sensitivity analysis, flavour rating was recommended as the selection criterion for genetic improvement of cup quality in Arabica coffee (Yigzaw, 2005).

2.6. Coffee Grading and Classification

A nation should establish a quality management system in developing a quality control /inspection assurance. A coffee standard is a document established by consensus and approved by a recognized body, which provides the common and repeated use, rules, guidelines or characteristics of activities for their results, aimed at achieving the optimum degree of order in a given context (Desse *et al*., 2008). The market at arrival Q (quality) grading system provides standards to capture the Q premium in the domestic market (ECX, 2009). Commercially, grade indicators are used to classify coffees where bean size, number of defects, altitude of growing, etc. are taken into account, depending on the producing country. In this sense, most producing countries have their own classification and grade charts (News Release, 2008**).** In Ethiopia, coffee grading is conducted through the combination of two methods. They are green coffee (raw bean) analysis and cup tests (liquoring or organoleptic analysis). Green coffee analysis involves visual inspection of physical characteristics of coffee bean. This includes screen analysis which makes size assessment, defect count, appearance or color test and shape which usually refers to the structure of beans .Cup test is based on roasted coffee analysis (chemical process) by which aroma; acidity, body and other flavour components are tested (Endale, 2007).

According to Ethiopian Commodity Exchange (ECX) grading system currently applied in the country since 2009. The ECX contracts of grading factors of unwashed coffee are categorized in to two categories: the raw value and cup quality value. The raw value scores 40% (defect=30%, odor=10%) and the cup quality value scores 60% (cup cleanness =15%, acidity=15%, body=15% flavour=15%) (ECX, 2009). Grading process by a panel of three (3) certified Q graders and 5 cups from each sample for sensory evaluation (Thomson, 2010).Generally, grading and classification is usually based on altitude and /or region, botanical variety, preparation, bean size, number of defects, bean weight, roast appearance and cup (Endale, 2008). On the other hand, recently ECX established a new grading system of the overall standard for raw and liquor quality grades for unwashed coffee. The grades range from 1 to 9 respectively. The standard Parameters and their respective values used for unwashed coffee raw quality evaluation and grading as per ECX (2009) presented in (Table 1). The following scoring key has proven to be a meaningful way to describe the range of coffee quality for the final score (ECX, 2009). Total quality classification scores: 90-100 Outstanding, 85-89.99 excellent specialties, 80-84.99 very good and < 80.0 below specialty coffee quality (Not specialty) (Wintgens, 2004). The general requirements: The moisture content of unwashed coffee shall not be more than 11.5% by weight and minimum 85% by weight of beans remain on top of screen 14 after sieving and Under Grade (UG) should fulfill sound bean % by weight <50% and flavours value score fair (ECX, 2009).

Table 1.Grading and quality classification of dry processed Arabica coffee

Grade	**Final Score**
Grade 1	91-100
Grade 2	81-90
Grade 3	71-80
Grade 4	63-70
Grade 5	58-62
Grade 6	50-57
Grade 7	40-49
Grade 8	31-39
Grade 9	20-30
Under Grade (UG)	15-19

Source: ECX Coffee Contracts, (2009) Coffee is assigned in one of 11 regional indications for unwashed coffee, and given a grade of 1-9, or UG (under grade) based on physical grading and basic cup evaluation. The quality of the final flavoured product is checked with a sensory evaluation technique known as "cupping" (FAO, 2010b).

Table 2.Commercial coffee grading and classification

Grading	Classification
A. Specialty Grade 1	Preliminary Grade 1 or 2 (NO 3)85+ Points
B. Specialty Grade 2	Preliminary Grade 1, 2&380+ Points
C. Commercial Grade 1	Preliminary Grade 1, 2&3<80 Points
D. Commercial Grade 2	Preliminary Grade 4
E. Commercial Grade 3	Preliminary Grade 5
F. Commercial Grade 4	Preliminary Grade 6
G. Commercial Grade 5	Preliminary Grade 7
H. Commercial Grade 6	Preliminary Grade 8
I. Commercial Grade 7	Preliminary Grade 9
J. Under Grade (U.G)	

Source: Reuters, (2009).

Specialty coffee grading in the ECX: unwashed and washed coffees that receive an initial grade of 1, 2, or 3 within the initial basic ECX grading will go through a secondary, full SCAA cupping and grading process by a panel of three (3) Certified ‘Q’ Graders. Coffees that receive a score of 85 and above will receive a “Specialty Grade 1” classification and coffees that receive a score of 80 and above will receive a “Specialty Grade 2” classification. These classes will be traded in the ECX under those grades **(**News Release, 2008).This adds an additional level of quality assurance for these two grades of coffee and ensures specialty coffees are identified and separated from the commercial grade coffees. These grade classifications will accompany with the regional and origin classifications of geographic indication (Reuters, 2009).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

On-farm processing experiments were carried out at three sites of state owned Limmu Coffee Plantation Enterprise (LCPE) in Jimma zone: Gomma-1 and Gomma-2 coffee farms are located in Gomma wereda whereas Kossa coffee farm is in Limmu Kossaa wereda. These coffee farms represent: lowland, medium highland and highland coffee growing areas with different agro-ecologies. The experimental station at Gomma-1 represents low altitude (1500m.),Gomma-2 represents mid-altitude (1650m) and Kossa coffee plantation represents higher altitude (1850m) a.s.l. Description of the study areas is presented in Table 3 and Fig.1.

Table 3. Description of the study area

Descriptions	**Gomma- 1**	**Gomma-2**	**Kossa**
Geographical location	$7^0 59^1$N&$36^0 42^1$E	$7^0 55^1$N&$36^0 37^1$E	$7^0 50^1$N&$36^0 53^1$E
Distance from jimma (km)	60	50	53
Altitudinal range of the farm (m.a.s.l)	1430-1800	1450-1750	1600-1950
-Altitude of the specific research station(masl)	1500	1650	1850
Temperature: Maximum(^{0}C)	28	27	25
Minimum(^{0}C)	14	13	12
Annual Rain-fall average (mm)	1143	1400	1680

Source*: Limmu Coffee Plantation Enterprise (LCPE) 2009/2010(Unpublished annual report))*

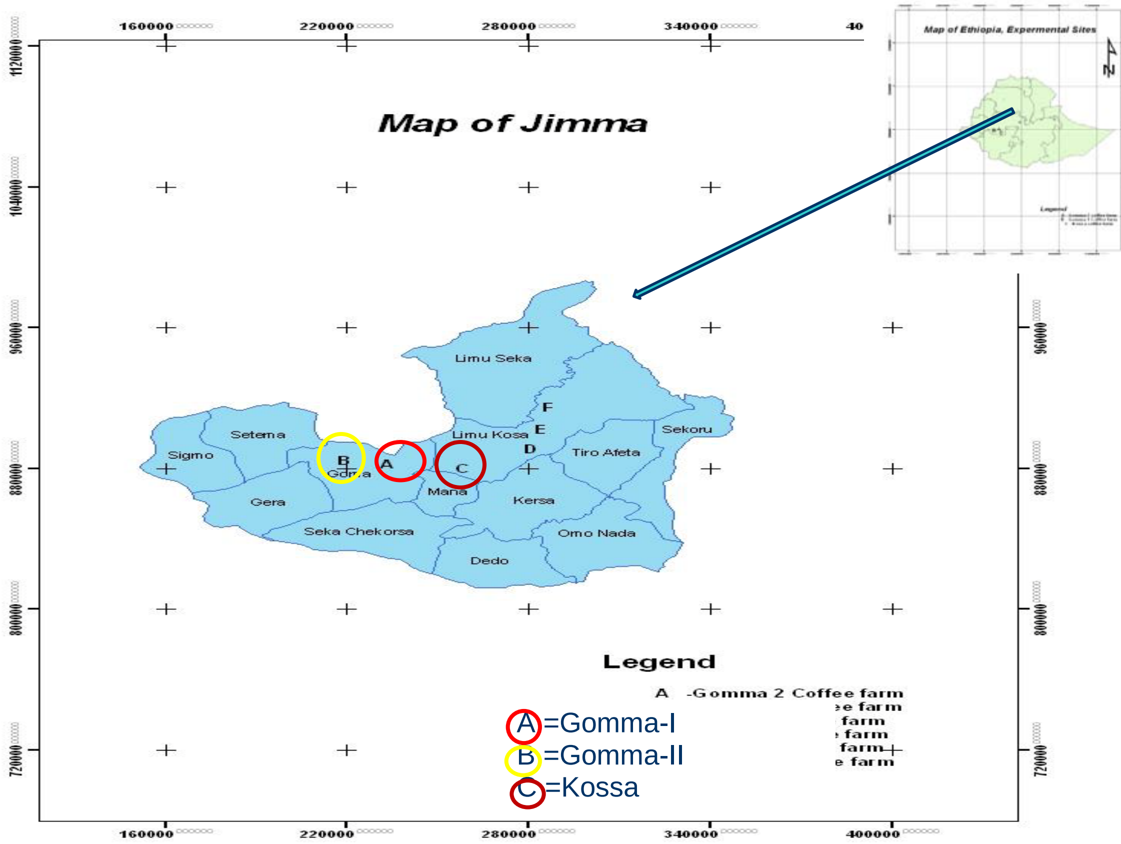


Figure 1 Map of Ethiopia and Experimental Sites

The quality analysis was conducted at Oromia Coffee Farmers Cooperative Union (OCFCU) coffee cupping laboratory in Addis Ababa.

3.2. Experimental Factors

The experiment has four factors, namely: location, drying method, coffee variety and cherry layer thickness. The major factor (main-plot) comprises location; representing lowland, midland and highland areas. The second factor (sub- plot) comprises drying materials: bricks floor, raised bed with bamboo mats and raised bed with mesh wire. The third factor (sub-sub-plot) contains coffee varieties: 744, 74110 and their mixture (744+74110) to simulate actual farmers practice (Table 4**).** The two Arabica coffee varieties representing the characteristics of big size (744) and small size (74110) beans and their mixture (big size 50 % + small size 50 %) were used for the study was presented on Appendix Table III**.** The fourth factor (sub-sub- sub-plot) comprises: four levels of layer thickness with the cherry weight of 20, 30 and 40 kg/m^2 uniformly treated and the farmers conventional practices of mixed drying of different days harvest (40 kg/m^2).

Table 4. Characteristics of coffee varieties

Cultivar	Special Feature	Bean Length Group	Mucilage	Raw Quality	Cup Quality	Commercial Acceptance
744	Open	long	Luxurious	Average/Good	Average	Acceptable
74110	compact	short	light	Average/Good	Good	Acceptable
744+74110		mixture				

Source*: IAR, 1996; Behailu et al., 2008*

The experimental area needed to lay out the experiment at each location was 200m^2 (20mx10m).The drying materials: bricks floor were partitioned in to 3 blocks (replications) to allocate the treatment combinations allowed to be laid on bricks floor. Similarly, each three raised drying tables, made up of bamboo mats and mesh wire with the length of 10m and width of 1m (10m x1m) (10m^2 areas) with a height of 0.8m, were compartmented using wooden frames. About 0.5 m^2 area were used as a plot to manage coffee loads with in each experimental unit. The space used between treatments, replications and blocks were 0.1m, 0.3m and 1.00m, respectively. About 1755kg of red ripe cherries were harvested at each location and laid on the basis of the desired treatment allocations. A total amount of 5265kg of red ripe cherries were used to undertake the experiment.

3.3. Experimental Design

The experiment was laid out in 3x3x3x4 Split- Split-Split plot design arranged in CRD with three replications at each location providing 108 treatments. Randomizations were held separately and independently for each replication where the treatments are assigned completely at random as described by Gomez and Gomez (1984) and Poduska (2008). Four factor analysis of variance model was used (Feder, 2007).

The model

$$\mathbf{Y_{ghijk} = \mu + b_g + A_h + \pi_{gh} + B_i + (AxB)_{hi} + \lambda_{ghi} + C_j + (AxC)_{hj} + (BxC)_{ij} + (AxBxC)_{hij} + \eta_{ghij} + D_k + (AxD)_{hk} + (BxD)_{ik} + (AxBxD)_{hik} + (CxD)_{jk} + (AxCxD)_{hjk} + (BxCxD)_{ijk} + (AxBxCxD)_{hijk} + \varepsilon_{ghijk}}$$

Where: Y_{ghijk} = the response measurement for the $_{ghijk}{}^{th}$ observation (overall quality coffee)

μ = the general mean effect.

b_g = the g^{th} location effect randomly distributed with mean zero and variance $\delta^2{}_b$,

A_h = the effect of the i^{th} level of locations

π_{gh} = a random error effect distributed with mean zero and variance $\delta^2{}_\pi$,

B_i = the effect of the i^{th} level of drying methods

$(AxB)_{hi}$ = the interaction effect of between location and drying methods

λ_{ghi} = a random error effect distributed with mean zero and variance $\delta^2{}_\lambda$,

C_j = the effect of the j^{th} level of variety

$(AxC)_{hj}$ = the interaction effect of between location and variety

$(BxC)_{ij}$ = the effect of the interaction between drying methods and variety

$(AxBxC)_{hij}$ = an interaction effect among locations , drying methods and variety

η_{ghij} = a random error effect distributed with mean zero and variance $\delta^2{}_\eta$,

D_k = the effect of the k^{th} level of layer thicknesses

$(AxD)_{hk}$ = an interaction effect between locations and level of layer thicknesses

$(BxD)_{ik}$ = an interaction effect between drying methods and level of layer thicknesses

$(AxBxD)_{hik}$ = an interaction effect among locations ,drying methods and level of layer thicknesses

$(CxD)_{jk}$ = an interaction effect between variety and level of layer thicknesses

$(AxCxD)_{hjk}$ = an interaction effect among locations ,variety and level of layer thicknesses

$(BxCxD)_{ijk}$ = an interaction effect among drying methods ,variety and level of layer thicknesses

$(AxBxCxD)_{hijk}$ = the effect of the interaction among locations, drying methods variety, and layer thickness

ε_{ghijk} = a random error effect distributed with mean zero and variance $\delta^2{}_\varepsilon$,

3.4. Experimental Procedure

The data was collected independently to identify the variability that exists among the three locations for quality attributes of unwashed Arabica coffee.

3.4.1. Harvesting

Coffee plantations having the desired varieties with in the age range of 12-20 years were obtained and ready for harvesting and identified as a source of red ripe cherries. Harvesting was done by hand at peak harvest period. The field processing was held from October 21 to November 17, 2010 at experimental sites.

3.4.2. On- farm processing

Primary processing was done immediately after harvesting; since the quality of the bean begins to be affected within hours after picking. The red cherries were labeled and properly spread on bricks floor and raised drying tables made up of bamboo mats and mesh wire. The red ripe cherries were carefully partitioned into levels of cherry drying layer thicknesses and laid on their plots at random according to the treatment allocations. The coffee layers regularly stirred four times during the day time at an interval of two hours starting at 10:00 am till 4:00 pm. The conventional system was maintained with mixed drying of cherries harvested on different days as practiced by farmers. At night and during rainy time dried cherries were covered with polyethylene sheets being two days after spreading on drying materials to hasten rate of dehydration. Coffee cherries were dried under open sun condition for two to three weeks until the moisture content dropped to less than 12%.

3.4.3. Hulling and packing

The hulling operation was carried out to release the coffee beans from the dried husk. It was done using hulling machine. The hulled coffee was cleaned and polished manually to sort undamaged beans. Each 500 g sample of green bean was packed and labeled with plastic bags for proper handling till quality analysis. Finally the samples were brought to the coffee quality laboratory (OCFCU).

3.4.4. Quality analysis

For further quality evaluation; clean coffee bean sample of 500 g was taken from each treatment combination based on sampling procedure set by Ethiopian standard (ESBN 8.001) and (MoA), which is on the basis of drawing 3 kg per 10 tons. Representative samples were drawn and laboratory size samples were prepared from bulk samples. For further physical and organoleptic analysis maximum of 350 g green coffee sample with optimum moisture content (11.5%) was prepared following the procedure described by ECX (2009).The quality analysis, which was carried out from March 11 to April 18, 2011.Green bean physical and cup quality characteristics were evaluated by three Q certified professional coffee tasters. Each sample was coded according to the standard procedure used for unwashed coffee raw and cup quality evaluation. The raw quality constitutes 40% (Defect=30% (primary defects=15% and secondary defects=15%) and Odor=10%) as indicated in Appendix Table VI.The cup quality value scores 60 % (Cup Cleanness =15%, Acidity =15%. Body=15% and Flavour = 15 %) of the over all coffee quality. The comparative sensorial tests describe a grading scale from 1 to 9 where 9 corresponded to the worst cup and 1to the best cup as per ECX procedure (ECX, 2009) as indicated in Appendix Table VII.

3.4.4.1. Raw coffee quality evaluation

As a general requirement for commencement of quality analysis, about 350 g of green coffee bean sample was prepared from each sample as per the procedure described by Specialty Coffee Association of America (SCAA, 2009) set as the standard conditions for the analysis of green coffee and organoleptic quality characteristic as indicated in Appendix Table VII.

.**Coding:** The samples collected from each treatment were assigned to arbitrary codes in order to secure unbiased judgments.

Moisture testing:. The moisture content of each sample bean was measured with a standard moisture tester certified in 2011 by Quality and Standard Authority of Ethiopia to maintain it within a permissible range (9-11.5%).

Screen analysis: Bean size distribution was evaluated by means of rounded perforated plate called screen. The size of the screen holes was specified in 1/64 inch. Since market acceptable bean size is above screen number 14, to obtain homogenous and healthy beans, samples were screened through a mesh sieve size on screen 14 and those retained above were used for analysis (ECX, 2009).

From each treatment a 350 g beans were passed through a series of sieves with round perforations of 14, 15, 16, 17, 18 and 19 and weighed to determine the percentage out of the total sample as the procedure set by (ISO, 2004a; EAFCA, 2008) as indicated in Appendix Table V.

Defects count: black beans, fungus damaged, sever insect damaged, foreign matter out of bean origin and foreign matter out of coffee origin were counted and scored out of 30% as the procedure set by ECX (2009). Out of a 350 g green coffee beans sampled from each treatment combinations; the number of defected beans with unacceptable physical character for full black, full sour, insect damaged, husk and foreign matter were recorded accordingly. The primary defects (count) scored (15%) and the secondary defect (by weight) counts scored (15%) respectively.

Bean weight: Weight of 100 beans for each sample was measured using sensitive balance.

3.4.4.2. Roasting

About 100 g of green coffee bean sample was taken from each treatment and roasted at temperature of 160^{o}C-200^{o}C for 6-7 minutes using sample roasting machine (Model PROBAT.Werke type Brz.6, Germany). After uniform roasting it was tipped out into a cooling tray. Immediately, cold air was blown though the coffee to induce rapid cooling off. When the roasted beans were cool enough (4 minutes on average), it was blown to remove the loose silver skins before grinding.

3.4.4. 3. Grinding

Grinding was carried out using coffee grinder (Mahlkolig Columbia, WLLB) with middle adjustment to at fine to medium size in a set of five cups. About 12 g of ground coffee sample was prepared for each cup, and got ready for brewing.

3.4.4.4. Brewing

The volume of water used for the preparation of the beverage was 240 ml per cup (12g of roasted and ground coffee per 240 ml of water). Using the preheating graduating cylinder, boiled water (93^0C) poured into cup containing the test portion and allowed the infusion to steep for approximately 3 minute to permit the ground settle and, then, sniffing the brewed coffee was carried out to analyze its aroma.

3.4.4.5. Coffee testing

Sensory evaluation was done using four quality criteria: cleanness, acidity, body and flavour, which were scored based on the standard and procedure outlined by ECX (2009). The coffee samples were medium roasted and medium ground. A team of three expertise, experienced and internationally certified Q grader cuppers were involved in evaluation of the coffee brew. They participated in a panel for cupping to evaluate the aroma and taste characteristics of each sample. Average result of cuppers was used for the analysis. For liquoring 5 cups were prepared by mixing 12 g of coffee powder in each cup with boiled water and stirring the content to ensure the homogeneity of the mixture for aromatic stringent and quality (ISO, 2000). The cup is then stirred, and any grounds that still float are removed. Tasting was carried out when the beverage cooled to around $60^o{}_C$ (palatable temperature) (ISO, 2000).

3.5. Data Collected

3.5.1. Field data

The primary processing activities held in the field was laid out as presented in Appendix Table III comprises:

Days to Drying: The length of drying period between date of harvesting and days to drying

Moisture content: The moisture content of each sample bean was measured with a standard moisture tester (Multi grain tester) certified and checked by Quality and Standard Authority of Ethiopia. When the moisture content of the dried cherry attained < 12% ,it became to be stored until further processing/hulling.

3.5.2. Laboratory analysis

The laboratory assessment on both physical and organoleptic quality evaluation comprises:

Percentage bean size determination: The percentage of coffee beans retained above screen size No.14.

Screen analysis: Bean size distribution was evaluated by means of rounded perforated plate called screen. The size of the screen holes was specified in 1/64 inch. The data measured based on coffee bean retained by screen between 14 and 19.Three samples were taken in random representing each treatment combinations.

Average hundred bean weight: The average weight of 100 beans from each sample was measured using sensitive balance (g).

Physical defects: Defects are manually separated and counted according to their type.

a) Primary defect (count): The primary defect points score :< 5 defect counts=15, points; 6-10 defects count=12 points; 11-15 defects count=9 points; 16-20 defects count=6 points; 21-25 defects count=3 points and >25 defect count=1.5 points.

b) Secondary defect (weight): The secondary defects (by wt) points score <5%=15 points; <10%=12 points; <15%=9 points; <20%=6 points; <25 %= 3 points and >25 %=1.5 points.

Odor: Olfaction evaluated as odor score: Clean (10); fair clean (8); trace (6); light (4); moderate (2) and strong (0) as per ECX (ECX, 2009).

Total raw value: The sum total of physical quality attributes.

Cleanness: Cup cleanness scores: Clean(15); Fair clean(12); one cup defect(9);two cup defect(6);three cup defect 3 and > 3 cup defect(0)

Acidity: cup acidity was evaluated as, pointed (15%), moderately pointed (12 %), medium (9 %), light (6 %) or lacking (3 %).

Body: Is synonymous with mouth feel and viscosity and/or linked with density viscosity of the brew. Cup body was evaluated as full (15 %), moderately full (12 %), medium (9 %), light (6 %), and thin (3 %).

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

Total cup quality: The sum total of sensory evaluation of each treatment

Total quality: the sum total of both physical and organoleptic values of each treatment.

According to commercial coffee grading (ECX, 2009) total quality classification scores describe the range of coffee quality for the final score:

- 90-100 = Outstanding specialties,
- 85-89.99 = Excellent Specialties,
- 80-84.99 =Very Good specialties and

< 80.0= Below Specialty coffee quality (Not Specialty)

Specialty coffee taste: Immediately after completion of the quality taste of each treatments, the total quality value is identified and those total quality values (>80) were re-checked whether the sampled quality fits specialty grade classification or not. Those treatments scoring the desired quality classification were identified and recorded based on the ECX format (Appendix Table vii) by cuppers.

Grading: To identify the status of coffee quality, evaluation of green coffee bean was carried out on the basis of raw (40%) and liquor (60%) quality characteristics. The overall standard for raw and liquor quality grades of unwashed coffee shows that: grade 1=91-100; grade 2=81-90; grade 3=71-80; grade 4=63-70; grade 5=58-62; grade 6=50-57; grade 7=40-49; grade 8=31-39; grade 9=20-30; under grade=15-19 (ECX, 2009).

3.6. Statistical Analysis

The data were checked for normality and subjected to Analysis of Variance (ANOVA) using SAS statistical software (version 9.2). Based on results of the homogeneity test, combined analysis was applied over locations as described by Roger (1994).When ANOVA showed significant differences, mean separation was carried out using Least Significant difference (LSD) test at 5 % and 1% level of significance (Gomez and Gomez, 1984).

4. RESULTS AND DISCUSSION

4.1. Drying Period

The three way interactions among location, drying materials and layer thickness showed significant differences ($P \leq 0.05$) in drying period of coffee cherries. However, there is no significant variation among the four ways and between two way interactions on the time of drying of cherries at the study sites. Accordingly; at Kossa ,when coffee cherries placed on raised beds covered with mesh wire using layer thickness loads of $40kg/m^2$ and treated as conventional practice took the longest time of drying (25 days). On the other hand, at Gomma-1 bricks floor using the density levels of 20 kg/m^2 took the shortest time of drying (10 days). The mean drying period (17 days) recorded at Gomma-2 when cherries placed on bricks and bamboo mats using the density levels of $40kg/m^2$ treated as conventional practices. There was a deviation of one week between the maximum and the average drying period of cherries at the study sites.

This could be due to the structural differences on the drying materials and variations on density of cherries determine the time of drying. When coffee is placed on raised beds covered with mesh wire using density levels of cherries $40kg/m^2$, took longer time to dry due to the sagging nature of mesh tables. While; when coffee is dried on bricks floors with the density levels of $20kg/m^2$,took shortest drying period as compared to raised beds covered with bamboo mats and mesh wire. This is because bricks have characteristics of high absorption of heat during the day time. As drying depth increased, there was a linear increase in drying time and vice versa. The above result supports the findings of Lower et al. (2007) who reported that coffee beans may require more days to dry depending on the methods of drying and the density at which the beans are dried. The result also agrees with the reports of ICO (2010), indicating that as good drying conditions, terraces perform better than tables because of higher temperature effect. Similarly, the result of the present study was also in agreement with the findings of Beza (2011), who reported that dry processed coffee on mesh wire took much longer time and coffee drying on bamboo mats and cement floor dried earlier. In general, the time taken to dry coffee cherries was shorter at Gomma-1, compared to the period required at Kossa. On the other hand, bricks floor resulted in shorter period (10 days) than did other drying materials across locations. Similarly, drying period increased with increasing thickness of cherry layer in all cases (Table 6).

Table 5. Interaction effects among location, drying material and layer thickness for drying period of coffee cherries

Location	**Drying Material**	**Levels of Layer Thickness (kg/m^2)**			
		20	30	40	40 (conv.)
Gomma-1	Bricks	10.22^{s}	12.22^{r}	14.22^{opq}	15.00^{no}
	Bamboo mats	12.11^{r}	14.00^{pq}	15.00^{no}	16.00^{lm}
	Mesh wire	12.33^{r}	14.33^{op}	16.00^{lm}	16.77^{jkl}
Gomma-2	Bricks	13.33^{q}	15.33^{mn}	17.33^{jk}	18.33^{hi}
	Bamboo mats	15.11^{mno}	16.55^{kl}	17.44^{jkl}	17.22^{jk}
	Mesh wire	16.66^{kl}	18.88^{fgh}	20.33^{de}	19.44^{efg}
Kossa	Bricks	16.55^{kl}	18.77^{gh}	19.44^{efg}	19.77^{gh}
	Bamboo mats	17.66^{ij}	19.66^{efg}	21.55^{bc}	21.55^{bc}
	Mesh wire	20.66^{cd}	22.44^{b}	24.55^{a}	24.55^{a}
LSD (5%)			0.905		
CV (%)			5.62		

Figures followed by the same letter(s) are not significantly different at P≤0.05.

Similarly; the result presented in Table 5 showed significant variations (P≤0.05) among coffee varieties with respect to days to drying. However, there was no significant variation among locations on the time of drying of cherries. Coffee variety 744 and the combination of the two varieties 744 +74110 took the longest time of drying. On the other hand, variety 74110 exhibited the shortest cherry drying period. This could be attributed to the differences in seed size, as the size of the cherries (beans) has an influence on the drying period. Coffee variety 744 is identified by its big size beans and luxurious mucilage which needs more time to dry than variety 74110, which is characterized by small sized beans and light mucilage. This result agrees with the findings of FAO (2010), indicating that coffee cherry with its intact outer pulp and large beans may require longer time to dry. Similar results have been reported by Solomon and Behailu (2006) and ICO (2010) showing that for Arabica coffee the length of drying period depends mainly on weather conditions and degree of moisture content and size of the cherries.

Table 6. Effect of variety on drying period of coffee cherries

Variety	**Drying period (days)**
744	18^{a}
74110	17^{b}
744+74110	18^{a}
LSD (5%)	0.146
CV (%)	5.62

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$.

4.2. Hundred Bean Weight

The interaction between location and drying material was highly significant ($P \leq 0.01$) for hundred bean weight of coffee (Fig.1). Dry processing carried out at Kossa using raised beds covered with bamboo mats resulted in the heaviest hundred bean weight 17.24g, Whereas the lowest hundred bean weight was recorded for bricks floor and raised bed covered with bamboo mats (14.53 and 14.66 g, respectively) at Gomma-2. The average hundred bean weight was 15.66 g with the range between 14.53 g and 17.24 g.The interaction between location and variety was also highly significant ($P \leq 0.01$) for hundred bean weights (Table 7). At Kossa, variety 744 scored the heaviest hundred bean weights (17.29 g), whereas, at Gomma-2 variety 74110 and 744 +74110 had resulted in the lowest hundred bean weight, 14.21 and 14.52 g, respectively. The average hundred bean weight was 15.65 g. There was 1.64 g deviation between the maximum and average hundred bean weight for coffee varieties across the study sites.

This variation could be attributed to the combined effect of differences in altitude of the locations and structure of the drying materials. At Kossa, the slow rate of maturation of berries probably favoured better fruit sets and increased the size and weight of beans. The present findings agree with the reports of FAO (2010), indicating that coffee beans grown at higher elevations tend to be denser, larger, and have better flavour. On the other hand, Wintgens (2004) reported that beans produced at low altitudes have a negative effect on the flavour and the structure of the beans due to accelerated maturation. The result of the present study also agrees with the findings of Mekonnen (2009) who reported that bean weight of coffee accessions is highly influenced by both coffee genotype and processing method.

Similarly, the combined effects of altitudinal differences and varietals characteristics have an influence in determining hundred bean weights of coffee beans. At highland and midland areas the big sized beans have more weight as compared to the small sized beans. Better bean setting is probably because of the lower temperature and thus, slow rate of maturation at higher altitudes. This result agrees with the findings of Van der Vossen et al. (1985) who reported that bean size and dry weight increased as elevation is higher. Wintegens (2004) has also reported that Arabica varieties were diverse with respect to average bean weight with values ranging between 9.2 g and 18.2 g. The findings of JARC (1996) also indicated that variety 744 is characterized by long beans and is suitable in all altitudes. While, variety 74110 characterized by short bean length is highly suitable in highland areas. Beza (2011) has also reported that the compact variety 74110 has the lowest hundred bean weight across locations. Tesfaye et al. (2008), indicating that the dry weight and size of beans are determined by differences in variety as well as thermal and moisture regimes across locations. Generally, at Kossa, wherein highly suitable altitude to the big sized beans (744) and high altitude, high rainfall and low temperature attributed to slow maturation period for increased in weight of beans.

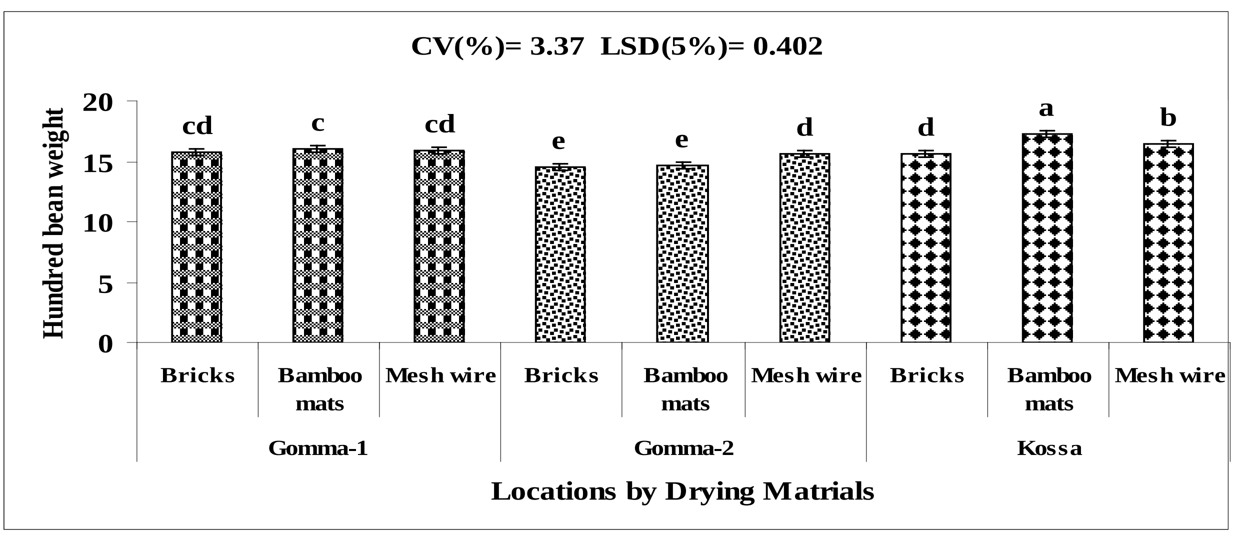


Figure 2. Interaction effects between location and drying material for hundred bean weight of coffee
Bars capped by the same letter(s) are not significantly different at P≤0.01

Table 5. Effects of interaction between location and variety for hundred bean weight (g) of unwashed Arabica coffee

Location	**Variety**			
	744	**74110**	**744+74110**	**Mean**
Gomma-1	16.13[c]	15.75[cd]	15.88[c]	15.92
Gomma-2	15.05[e]	14.21[f]	14.52[f]	14.59
Kossa	17.29[a]	15.32[de]	16.77[b]	16.46
Mean	16.15	15.09	*15.72*	*15.65*
LSD (P≤0.01)		0.509		
CV (%)		3.371		

Figures followed by the same letter(s) are not significantly different at P≤0.01

On the other hand, there was no significant variation among the four ways interaction effects for hundred bean weight of coffee at the study sites. However, the analysis of variance showed significant variations (P≤0.01) among the three way interaction effects in sun drying methods, coffee varieties and density of cherries (Table 8). Drying coffee variety 744 on raised beds covered with bamboo mats using layer thickness loads of 20 to 40kg/m^2 and the conventional practices produced statistically identical and highest hundred bean weight with respective values of 16.55 and 16.74 g,and 16.43 and 16.48 g. On the other hand, coffee variety 74110 dried on bricks floor using the density levels of 30 and 40 kg/m^2 resulted in statistically identical and the lowest hundred bean weight with respective values of 14.72 and 14.48 g. The mean hundred bean weight recorded was 15.66 g. There was a deviation of 1.08 g between the maximum and mean hundred bean weight at the study sites.

This result is in agreement with the findings of Mekonnen (2009) who indicated that bean weight of coffee is highly influenced by both coffee genotypes and processing methods. Furthermore, Wintegens (2004) reported that Arabica varieties are diverse in respect to average bean weight with values ranging between 9.2 and 18.2 g.

Table 6. Effects of interaction among drying material, variety and layer thickness on hundred bean weight (g) of unwashed coffee

Drying Material	Variety	Levels of Layer thicknesses (kg/m2)			
		20	30	40	40 (conv.)
Bricks	744	15.83^{abcdefghi}	15.68^{bcdefghij}	15.96^{abcdefgh}	15.73^{bcdefghij}
	74110	14.96^{hijk}	14.72^{jk}	14.48^{k}	15.03^{hijk}
	744+74110	15.41^{fghijk}	15.40^{fghijk}	15.40^{fghijk}	15.23^{ghijk}
Bamboo mats	744	16.55^{ab}	16.74^{a}	16.43^{abcd}	16.48^{abc}
	74110	15.48^{defghij}	14.92^{ijk}	15.34^{fghijk}	15.23^{ghijk}
	744+74110	16.10^{abcdefg}	15.95^{abcdefgh}	16.28^{abcdef}	16.42^{abcde}
Mesh wire	744	16.43^{abcd}	16.17^{abcdefg}	16.21^{abcdefg}	15.64^{bcdefghij}
	74110	15.33^{fghijk}	15.43^{efghijk}	15.08^{hijk}	15.10^{hijk}
	744+74110	15.53^{cdefghij}	15.45^{defghijk}	15.43^{efghijk}	16.10^{abcdefg}
LSD (1%)			0.990		
CV (%)			3.371		

Figures followed by the same letter(s) are not significantly different at P≤0.01

4.3. Bean Size

There was no significant variation among the four way and two way interaction effects on the proportion of percentage bean size of coffee retained on screen No. 14. But, significant (P≤0.05) variations were observed in the three way interactions of location, drying material and cherry layer thickness. Accordingly, at Kossa raised beds covered with bamboo mats and mesh wire with the density levels of 20 to 40kg/m^2 resulted in the highest percent of beans retained on screen size 14, where as, the lowest percent bean size was recorded for bamboo mats and bricks floor at Gomma-2 (Table 9). The average percentage bean size was 97.07.

High temperature effect and condensation nature of bricks and bamboo mats at Gomma-2 might have contributed to the reduction in size of beans. The result obtained in this study was in agreement with the finding of De Sausa and Roberto (2010) who reported that the size of the bean, although partly genetic, can be modified by ecological conditions, crop husbandry, post-harvest processing and handling practices. Mekonen (2009) has also showed that bean size, expressed as above screen size, is influenced by the interaction between processing methods and varieties. Moreover, Tesfaye et al. (2008) reported that soil moisture/rain fall would contribute more in determining coffee bean size.

Table 7. Interaction among locations, drying materials and layer thicknesses as affecting percent bean size of dry processed coffee

Location	Drying material	Levels of Layer Thicknesses (kg/m^2)			
		20	30	40	40 (conv)
Gomma-1	Bricks	97.44^{defg}	97.22^{efgh}	97.22^{efgh}	97.55^{cdefg}
	Bamboo mats	98.44^{abcd}	98.22^{abcde}	98.00^{abcde}	98.00^{abcde}
	Mesh wire	97.88^{abcdef}	97.88^{abcdef}	98.00^{abcde}	97.66^{bcdef}
Gomma-2	Bricks	94.77^{lm}	95.88^{ijkl}	96.22^{hij}	95.00^{klm}
	Bamboo mats	95.55^{jkl}	93.88^{m}	96.77^{fghi}	95.33^{jkl}
	Mesh wire	97.44^{defg}	96.00^{ijkl}	96.44^{ghij}	95.88^{ijkl}
Kossa	Bricks	95.55^{jkl}	95.66^{ijkl}	95.55^{jkl}	96.22^{hij}
	Bamboo mats	98.66^{abc}	99.00^{a}	98.44^{abcd}	98.77^{ab}
	Mesh wire	98.88^{a}	98.11^{abcde}	98.77^{ab}	98.11^{abcde}
LSD (5%)		1.180			
CV (%)		1.31			

Figures followed by the same letter(s) are not significantly different at P≤0.05

4.4. Raw Coffee Quality

Raw coffee quality evaluation of green coffee bean sample was prepared from each sample to determine the percentage defect counts and weight of primary (15%) and secondary (15%) defects and odor score (10%) was assessed as the procedure set by ECX (2009).

4.4.1. Primary defects

The raw quality analysis showed significant (P≤0.05) variations among the four way interactions of location, drying material, variety and cherry layer thickness for primary defect counts (Table 10). At Gomma-1, variety 744 with the density level of 20 to 40kg/m^2, variety 74110 and 744+74110 dried on bricks using similar loads and the conventional practice showed statistically similar and the highest mean primary defect score (15) points. Coffee varieties dried on raised beds covered with both bamboo mats and mesh wire using the density levels of 20 to 40k/m^2 and the farmers' conventional practices also resulted in statistically similar and the highest mean primary defect score (15 points). Also, similar results were obtained at Gomma-2 and at Kossa. However, at Gomma-2 variety 74110 dried on bricks floor with density levels of 40 kg/m^2

recorded the lowest mean primary defect value (6.00). The mean primary defects value counted over locations was 14.36. This could be related to high rain fall incidence during the study period and occurrence of insect damaged beans particularly in the samples taken from Gomma-2. Coffee processed on bricks floor using the conventional practice showed maximized the primary defects.

Table 8. Four ways interaction effects among location, drying materials, variety and layer thickness on primary defects score values of dry processed coffee

Location	**Drying materials**	**Variety by Layer thickness (kg/m^{2})**											
		744				**74110**				**744 + 74110**			
		20	**30**	**40**	**Conv(40)**	**20**	**30**	**40**	**Conv(40)**	**20**	**30**	**40**	**Conv(40)**
Goma-1	Bricks	15.00^{a}	15.00^{a}	15.00^{a}	13.00^{b}	15.00^{a}	15.00^{a}	14.00^{ab}	14.00^{ab}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
	Bamboo Mat	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
	Wire Mesh	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
Goma-2	Bricks	15.00^{a}	11.00^{c}	9.00d^{e}	8.00^{e}	8.00^{e}	8.00^{e}	6.00^{f}	9.00^{de}	15.00^{a}	10.00^{cd}	9.00^{de}	10.00^{cd}
	Bamboo Mat	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
	Wire Mesh	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
Kosa	Bricks	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
	Bamboo Mat	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
	Wire Mesh	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}	15.00^{a}
LSD ($P \leq 0.05$)	1.118												
CV (%)	4.82												

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

4.4.2. Secondary defects

With regards to secondary defects, the four ways interaction effects among location, drying material, variety and cherry drying layer thickness showed significant ($P \leq 0.05$) variations (Table 11). The highest secondary defects value (2.15) was obtained at Gomma-2, with the combination of variety 74110 dried on raised beds covered with mesh wire using the layer thickness loads of 20kg/m^2. Moreover, at Gomma-1, variety 744, 74110 and 744+74110 dried on raised beds covered with bamboo mats using the layer thickness loads of 20kg/m^2 exhibited statistically similar and the highest mean secondary defect values ranging from 1.85 to 1.93. Similarly, at Gomma-2 and Kossa, combination of the above three varieties with the layer thickness loads of 20 to 40kg/m^2 dried on raised beds produced statistically similar results for secondary defects score .On the contrary; at Gomma-1, when coffee variety 744 and 74110 dried on bricks floor using the density levels of 20 to 40kg/m^2 and the conventional practices resulted statistically identical and the lowest scores of secondary defects ranging from 1.12 to 1.14. Also, variety 744+74110 with loads of 40kg/m^2 and the conventional practice imparted the lowest mean secondary defects values ranging from 1.12 to 1.48. Similarly; at Gomma -2, variety 744, 74110 and 744+74110 dried on bricks floor using 20 to 40kg/m^2 and the conventional practices imparted the lowest mean secondary defects values scored 1.12. Also; at Kossa, when coffee variety 744 and 744+74110 dried on bamboo mats with the density levels of 40 kg/m^2 treated in the conventional practice resulted statistically identical and the lowest mean secondary defects values ranging from 1.12 to 1.21. Also, variety 744 dried on mesh wire with the cherry loads of 30 to 40kg/m^2 treated in the conventional practice and variety 744+74110 dried on raised beds covered with mesh wire with the cherry loads 40kg/m^2 produced the lowest mean secondary defects value (1.12).

Among defects observed in this study, the major ones are foxy and pest damaged beans which enhanced quality deterioration. Furthermore, the farmers' practice of mixed drying of different days harvest induced rewetting of beans and resulted in foxy appearance. Particularly at Gomma-2, there was rain for three days during the study period which may contribute in maximizing the amounts of secondary defects. Moreover, coffee dried on bricks floor was exposed to rewetting and, thus, induced foxy appearance. This result was in agreement with the finding of Desse (2008) who reported that, although the inherent flavour of Jimma coffee is pleasantly winy, some of the common cup defects are earthy, musty with secondary cup defects of taints in the liquor, which are mainly due to post harvest management problems. Similarly, the result was in line with the report of CLU (2007) indicating that foxy beans commonly observed in locally prepared dry coffee and coffee dried on bricks floor. The result of the present study also agrees with the findings of Farah et al. (2006) who reported that foxy appearance indicates a specific problem with the processing that will also be apparent in the next step, cupping of the samples.

Table 9. Effects of interaction among location, drying materials, variety and layer thickness for secondary defects of dry processed coffee

Location	Drying materials	Variety by Layer thickness (kg/m^2)											
		744				74110				744 + 74110			
		20	30	40	Conv(40)	20	30	40	Conv(40)	20	30	40	Conv(40)
Goma-1	Bricks	1.41^{hijk}	1.12^{k}	1.41^{hijk}	1.12^{k}	1.48^{ghij}	1.39^{hijk}	1.12^{k}	1.39^{hijk}	1.66^{cdefgh}	1.51^{fghij}	1.12^{k}	1.12^{k}
	Bamboo Mat	1.91^{abcde}	1.41^{hijk}	1.32^{ijk}	1.21^{jk}	1.93^{abcd}	1.12^{k}	1.21^{jk}	1.12^{k}	1.85^{abcde}	1.30^{ijk}	1.12^{k}	1.12^{k}
	Wire Mesh	1.99^{abc}	2.04^{ab}	1.32^{ijk}	1.12^{k}	1.91^{abcde}	1.32^{ijk}	1.32^{ijk}	1.12^{k}	1.85^{abcde}	1.67^{cdefgh}	1.41^{hijk}	1.12^{k}
Goma-2	Bricks	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.21^{jk}	1.12^{k}	1.12^{k}	1.12^{k}
	Bamboo Mat	1.32^{ijk}	1.12^{k}	1.39^{hijk}	1.12^{k}	1.91^{abcde}	1.12^{k}	1.39^{hijk}	1.12^{k}	1.85^{abcde}	1.21^{jk}	1.12^{k}	1.12^{k}
	Wire Mesh	1.99^{abc}	1.39^{hijk}	1.21^{jk}	1.12^{k}	2.15^{a}	1.49^{ghij}	1.48^{ghij}	1.12^{k}	2.04^{ab}	1.99^{abc}	1.12^{k}	1.12^{k}
Kosa	Bricks	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.32^{ijk}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}	1.12^{k}
	Bamboo Mat	1.59^{efghi}	1.99^{abc}	1.51^{fghij}	1.21^{jk}	2.10^{ab}	1.99^{abc}	1.93^{abcd}	1.85^{abcde}	1.93^{abcde}	1.93^{abcd}	1.99^{abc}	1.12^{k}
	Wire Mesh	1.62^{defghi}	1.39^{hijk}	1.49^{ghij}	1.21^{jk}	1.91^{abcde}	1.99^{abc}	1.81^{bcdefg}	1.67^{cdefgh}	1.84^{abcdef}	1.78^{bcdefg}	1.30^{ijk}	1.60^{defghi}
LSD ($P\leq0.05$)		*0.33*											
CV (%)		*14.40*											

Figures followed by the same letter(s) are not significantly different at $P\leq0.05$

4.4.3. Odor

There was no significant variation among the four and between the two way interactions for odor of coffee across locations. However, the three way interaction effects among the location, variety and level of cherry layer thickness showed significant variations *($P \leq 0.05$)* for odor of dry processed coffee. The highest mean odor values were detected for the various treatment combinations: variety 744, 74110 and 744+74110 with layer thickness loads of 20 to 40 kg/m^2 at Gomma-1 and, variety 744 and 74110 using the layer thickness loads of 20 to 40kg/m^2 and variety 744+74110 using the density levels of 20 and 30kg/m^2 at Gomma-2 produced the maximum proportion of mean odor and detected as clean odor (Table12). Furthermore; at Kossa, variety 744 with the layer thickness loads of 20 and 30kg/m^2, variety 74110 and 744+74110 using the density levels of 20 to 40kg/m^2 scored the maximum proportion of mean odor and detected as clean odor. However; at Gomma-1, variety 74110 and 744+74110 using the density levels of 40kg/m^2 treated in the conventional system and, variety 744 and 74110 at Gomma-2 scored the lowest value 8.66 to 8.88 detected to be fairly clean odor. The overall mean odor score value was 9.61.The possible reasons could be in the traditional system due to the exposure of cherries to re-wetting, which induced off-flavours on the natural odor of green beans.

Table 10. Interaction effects among location, variety and layer thickness for odor quality of green coffee bean

Location	**Variety**	**Levels of Layer Thicknesses (kg/m^2)**			
		20	**30**	**40**	**40 (conv.)**
Gomma-1	744	10.00^{a}	10.00^{a}	9.77^{ab}	9.55^{abc}
	74110	9.77^{ab}	10.00^{a}	9.55^{abc}	8.66^{e}
	744+74110	10.00^{a}	10.00^{a}	9.77^{ab}	8.66^{e}
Gomma-2	744	10.00^{a}	9.55^{abc}	9.55^{abc}	8.66^{e}
	74110	9.77^{ab}	9.55^{abc}	9.77^{ab}	8.88^{de}
	744+74110	9.66^{ab}	9.77^{ab}	9.33^{bcd}	9.11^{cde}
Kossa	744	10.00^{a}	9.77^{ab}	9.33^{bcd}	9.33^{bcd}
	74110	10.00^{a}	10.00^{a}	9.55^{abc}	10.00^{a}
	744+74110	10.00^{a}	9.55^{abc}	9.55^{abc}	9.33^{bcd}
LSD (5%)			0.518		
CV (%)			5.80		

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

Similarly; the three way interaction effects presented in Table 13 revealed significant variations *($P \leq 0.05$)* among the drying methods, coffee varieties and level of layer thicknesses with regard to odor quality of dry processed coffee at the study sites. As a result, variety 744, dried on bricks floor using the density levels of 20Kg/m^2 revealed the highest mean odor value detected to be clean odor score. Similarly, variety 744, 74110 and 744 +74110 dried on raised beds covered with bamboo mats and mesh wire using the density levels of 20 to 40Kg/m^2 and 20 to 30 Kg/m^2 exhibited statistically similar and the highest mean odor value detected as clean odor. On the other hand; variety 744 and mixture of the two varieties 744+74110 dried on bricks using the density levels of 40Kg/m^2 and treated in the conventional system resulted in the lowest mean values detected as fair clean odor.

The possible reasons for this could be the combined effect of processing methods, varietal characteristics and levels of cherry layer thicknesses which could have determined green coffee bean odor. As a result, bricks floor having in contact with undesirable elements and incidence of re-wetting of cherries by rain and dews might have favoured mould development and facilitated deterioration by inducing off-flavours. Whereas, drying tables performed better because of ample air movement and limited condensation and, thus, maintaining the natural odor of coffee bean. The finding of the present work supports the reports of ICO (2010) and Subedi (2010), indicating that coffee dried on bricks floor in contact with soil becomes dirty and blotchy, resulting dull aroma and earthy flavour in the beverage. Drying tables covered with wire mesh or mats would protect the crop from re-wetting, since tables provide two surfaces for moisture loss. Similar results have been reported by Silvano (2004) and FAO (2010a) for Arabica coffee processing on drying tables covered with mesh wire or mats, favouring in protection of the dried coffee from re-wetting.

Table 11. Interaction among sun- drying methods, variety and layer thicknesses for odor score of dry processed coffee

Drying materials	Variety	Levels Layer Thicknesses (kg/m^2)			
		20	**30**	**40**	**40 (conv.)**
	744	10.00^{a}	9.33^{cde}	8.66^{fg}	8.44^{gh}
Bricks	74110	9.77^{abc}	9.55^{abcd}	8.88^{efg}	9.33^{cde}
	744+74110	9.77^{abc}	9.33^{cde}	8.88^{efg}	8.00^{h}
	744	10.00^{a}	10.00^{a}	10.00^{a}	9.77^{abc}
Bamboo mats	74110	9.77^{abc}	10.00^{a}	10.00^{a}	9.11^{def}
	744+74110	10.00^{a}	10.00^{a}	9.77^{abc}	9.33^{cde}
	744	10.00^{a}	10.00^{a}	10.00^{a}	9.44^{bcd}
Mesh wire	74110	10.00^{a}	10.00^{a}	10.00^{a}	9.11^{def}
	744+74110	9.88^{ab}	10.00^{a}	10.00^{a}	9.77^{abc}
LSD (5%)			5.183		
CV (%)			5.80		

Figures followed by the same letter(s) are not significantly different at P≤0.05

4.4.4. Total raw coffee quality

The analysis of variance for the four way interactions among location, drying materials, variety and levels of layer thickness showed significant *(P≤0.05)* variation for the total raw quality of coffee (Table 14). Accordingly, at Gomma-1, variety 744 dried on raised beds covered with mesh wire using the density levels of 20 to 30kg/m^2 resulted in the highest mean total raw quality score (35.00 and 36.00).Similarly at Gomma-2, coffee variety 744 and 74110 dried on raised beds covered with mesh wire using the density levels of 20kg/m^2 and variety 744+74110 with the layer thickness loads of 20 to 30kg/m^2 scored statistically similar and the highest mean total raw quality values ranging from 35.00 to 38.00. Furthermore; at Kossa, variety 744 dried on raised beds covered with bamboo mats using the layer thickness loads of 20kg/m^2 ; variety 74110 using the density levels of 20 to 30kg/m^2 and variety 744+74110 with 40 kg/m^2 resulted in statistically similar and the highest mean total raw quality values ranging from 35.00 to 37.00. Variety 74110 dried on raised beds covered with mesh wire using the density levels of 30kg/m^2 also showed the highest mean total raw quality score (35.00). However, at Gomma-2, variety 744 dried on bricks floor with the layer thickness loads of 40kg/m^2 and the conventional practice using similar loads revealed statistically similar and the lowest total raw quality values ranging between 18.16 and 19.16. Furthermore; variety 74110 using the density levels of 20 to 40kg/m^2 and the conventional practice scored statistically similar and the lowest mean total raw quality score (16.16 to 18.83).Variety 744+74110 using the density levels of 40kg/m^2 and the conventional practice of drying also resulted in the lowest total raw quality values ranging from 19.16 to 19.50.

This could be attributed to the combined effect of environmental factors and post harvest management practices. As a result; at Gomma-2, there was an incidence of rain for three days during drying of cherries and coffee dried on bricks floor in particular had direct contact with foreign matter and was more exposed to re-wetting of cherries, causing quality deterioration of beans. While, raised beds with thick layers favoured mould development and induced blotchy and foxy nature of beans. In general ,inappropriate post harvest management practices causing further fermentation and slow dehydration increased the reddish black (foxy) bean formation, maximized the amount of defects and deteriorated the odor and colour of coffee and finally affected the over all raw quality of green beans. Hence, the results of the present study showed that conventional processing practices may lead to poor coffee quality. It also revealed that at lower and medium altitudes raised beds covered with mesh wires and in highlands using bamboo mats with thin layer thickness loads may be advantageous for better raw coffee quality characteristics. These findings are quit in agreement with the reports of Musebe et al. (2007) and ICO (2010), indicating that sun-drying of coffee on raised beds under good ambient conditions is an effective method for producing improved high quality coffee .The results of the present study also support the findings of Hicks (2002) who reported that mixing different types of coffee or different days of harvest greatly affects the final quality of the green bean.

Table 12. Effects of interaction among locations, drying materials, variety and layer thicknesses on total raw quality score values of dry processed coffee

Location	Drying materials	Variety by Layer thickness (kg/m^2)											
		744				**74110**				**744 + 74110**			
		20	**30**	**40**	**Conv(40)**	**20**	**30**	**40**	**Conv(40)**	**20**	**30**	**40**	**Conv(40)**
Goma-1	Bricks	28.50^{hijklm}	26.50^{lmnop}	27.83^{jklmno}	23.16^{pqrs}	29.50^{ghijkl}	29.00^{hijkl}	24.16^{opqr}	27.33^{jklmno}	31.50^{efghi}	29.50^{ghijkl}	25.83^{lmnop}	24.50^{nopqr}
	Bamboo Mat	34.00^{bcdef}	28.50^{hijklm}	28.00^{ijklmn}	27.00^{klmno}	33.33^{bcdef}	26.50^{lmnop}	27.00^{klmno}	25.16^{mnop}	33.0^{0cdefg}	27.50^{jklmno}	26.50^{lmnop}	25.16^{mnop}
	Wire Mesh	35.00^{abcde}	36.00^{abc}	28.00^{ijklmn}	26.50^{lmnop}	34.00^{bcdef}	28.00^{ijklmn}	28.00^{ijklmn}	24.50^{nopqr}	33.00^{cdefg}	31.00^{fghijk}	28.50^{hijklm}	25.83^{lmnop}
Goma-2	Bricks	26.00^{lmnop}	21.16^{qrst}	19.16^{tu}	18.16^{tu}	18.83^{tu}	18.16^{tu}	16.83^{u}	16.16^{u}	26.33^{lmnop}	20.83^{rst}	19.16^{tu}	19.50^{stu}
	Bamboo Mat	28.00^{ijklmn}	26.50^{lmnop}	29.00^{hijkl}	25.83^{lmnop}	34.00^{bcdef}	26.50^{lmnop}	29.00^{hijkl}	25.16^{mnop}	33.00^{cdefg}	27.00^{klmno}	25.83^{lmnop}	25.83^{lmnop}
	Wire Mesh	35.00^{abc}	29.00^{hijkl}	27.00^{klmno}	24.83^{mnopq}	38.00^{a}	29.00^{hjkl}	29.50^{ghjkl}	25.83^{lmnop}	35.66^{abcd}	35.00^{abcde}	26.50^{lmnop}	26.50^{lmnop}
Kosa	Bricks	26.50^{lmnop}	25.83^{lmnop}	24.50^{nopqr}	24.50^{nopqr}	28.00^{ijklmn}	26.50^{lmnop}	25.16^{mnop}	26.50^{lmnop}	26.50^{lmnop}	25.16^{mnop}	25.16^{mnop}	24.50^{nopqr}
	Bamboo Mat	30.50^{fghijk}	35.00^{abcde}	29.50^{ghijkl}	27.00^{klmno}	37.00^{ab}	35.00^{abcde}	34.00^{bcdef}	33.00^{cdefg}	34.00^{bcdef}	34.00^{bcdef}	35.00^{abcde}	26.50^{lmnop}
	Wire Mesh	31.00^{fghij}	28.00^{ijklmn}	29.00^{hijkl}	27.00^{klmno}	34.00^{bcdef}	35.00^{abcde}	33.00^{cdefg}	31.00^{fghij}	33.00^{cdefg}	32.00^{efghi}	27.50^{jklmno}	30.00^{ghijk}
LSD ($P \leq 0.05$)							3.73						
CV (%)							8.22						

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

4.5. Organolephtic Quality

4.5.1. Cleanness

Cup cleanness, an indicator of freeness from off-flavours was not significantly affected by the four and three way interactions. However, there were significant ($P \leq 0.01$) variations between the two way interaction of locations and sun-drying methods (Fig. 2). Accordingly, both at Gomma-1 and Gomma-2, processing coffee on bricks floor and raised beds covered with bamboo mats or mesh wire, and at Kossa drying coffee on both raised beds covered with bamboo mats and mesh wire resulted in statistically similar and maximum mean cleanness values detected as clean score. On the other hand, at Kossa, coffee dried on bricks floor had the lowest mean cleanness value and was detected as fair clean score.

The possible reasons for this could be differences in environmental factors, such as rain fall, altitude and temperature, and the processing methods determine the cleanness quality of coffee. This could be due to the fact that bricks floor is in direct contact with foreign matter, the soil surface and exposed to re-wetting of cherries with rain or dews inducing off-flavours. The findings of the present study support the work of Subedi (2010) who confirmed that coffee dried on bricks floor in contact with soil becomes dirty and blotchy, resulting in dull aroma and earthy flavour of the beverage. Similar results have been reported by Selmar et al. (2006) and ICO (2010), indicating that Arabica coffee drying tables covered with mesh or mats are used to minimize re-wetting, since tables have two surfaces for moisture loss or air movement and may result in better quality.

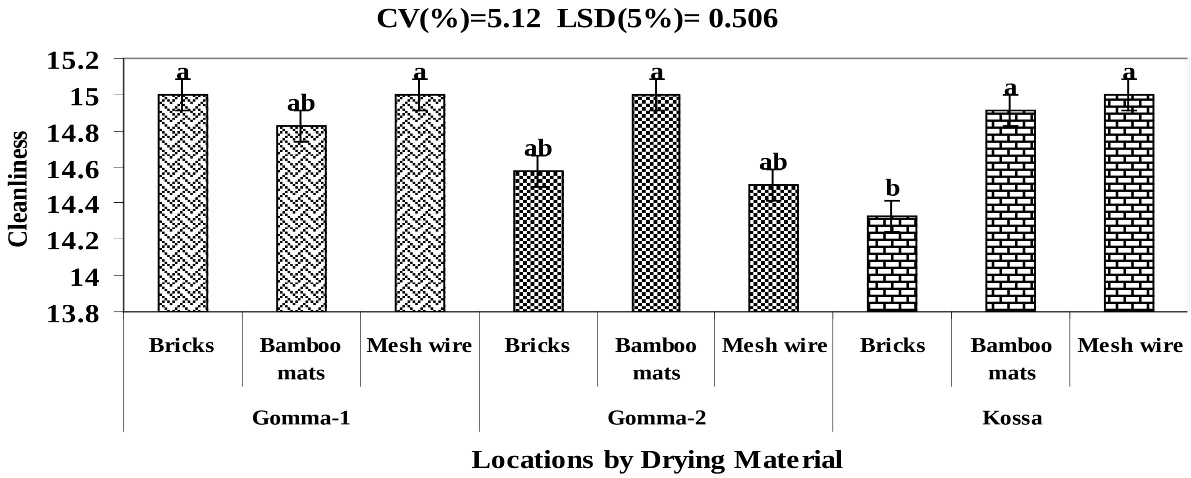


Figure 3. Interaction between location and drying material on cup cleanness score of unwashed Arabica coffee

Bars capped by the same letter(s) are not significantly different at P≤0.01

Similarly, the interaction between location and cherry layer thickness showed significant variations (*P≤0.01*) for cup cleanness (Table 15). In line with this, layer thickness loads of 20 to 40kg/m^2 in all the three locations and the farmers' conventional practice of mixed drying with the density levels of 40kg/m^2 across location, except coffee dried on bricks floor at Gomma-2,using conventional practices resulted in significantly higher mean cup cleanness values ranging from14.66 to15.00 and was detected as clean score. At Gomma-2, coffee drying with loads of 40 kg/m^2 treated in conventional way, resulted in the lowest mean cleanness value (13.88) detected as fair clean score.

The farmers' conventional practice using mixed drying of different days of harvest encourages re-wetting of cherries inducing mould development and quality deterioration. It could develop foxy colors and off-flavours that in turn affect cup cleanness quality. The result obtained in the present study was in agreement with that of Prodolliet (2004) reported that producing quality coffee is not a matter of chance; instead it is the result of planned and systematic activities, preventive measures and precautions taken to ensure the quality of coffee. Negussie et al. (2009) have also reported that properly processed coffee is free of off-flavour and defective beans having balanced and good acidity, body and flavour.

Table 13. Interaction effects between location and layer thickness on cup cleanness score of unwashed Arabica coffee

Location	**Layer Thicknesses (kg/m2)**				
	20	**30**	**40**	**40 (conv.)**	**Mean**
Gomma-1	15.00[a]	15.00[a]	14.77[a]	15.00[a]	14.94
Gomma-2	15.00[a]	14.88[a]	15.00[a]	13.88[b]	14.69
Kossa	14.77[a]	14.88[a]	14.66[a]	14.66[a]	14.74
Mean	14.92	14.92	14.81	14.51	14.79
LSD (1%)			0.407		
CV (%)			5.12		

Figures followed by the same letter(s) are not significantly different at $P \leq 0.01$

Furthermore, the interaction between the sun drying methods and cherry layer thicknesses showed significant ($P \leq 0.01$**)** variations for the cup cleanness of dry processed Arabica coffee (Table 16). Processing coffee on bricks floor and raised beds covered with bamboo mats and mesh wire with layer thickness loads of 20 to 40kg/m^2 and conventional practice on bamboo mats and mesh wire resulted in statistically similar and the highest cup cleanness mean values ranging from 14.66 to 15.00 and was detected as clean coffee score. On the contrary, drying coffee on bricks floor using the layer thickness loads of 40kg/m^2 treated as conventional practice exhibited the lowest cup cleanness mean value (14.22) and was detected as fair clean coffee score.

The farmers' conventional practices using different days of harvest on bricks floor was exposed to re-wetting of cherries and favored the growth of moulds that deteriorate coffee quality attributes. The result agrees with the findings of Negussie et al. (2009), properly processed coffee is free of off-flavour having balanced and good acidity, body and flavour.

Table 14. Interaction effects between sun- drying methods and layer thickness on cup cleanness quality of unwashed Arabica coffee

Drying Materials	Layer Thicknesses (kg/m^2)				
	20	30	40	40(conv.)	Mean
Bricks	14.88[a]	14.77[a]	14.66[ab]	14.22[c]	14.63
Bamboo mats	14.88[a]	15.00[a]	14.77a	15.00[a]	14.91
Mesh wire	15.00[a]	15.00[a]	15.00[a]	15.00[a]	15.00
Mean	14.92	14.92	14.81	14.74	14.85
LSD (5%)			0.407		
CV (%)			5.12		

Figures followed by the same letter(s) are not significantly different at $P \leq 0.01$

4.5.2. Acidity

The four way interaction among location, drying material, coffee variety and level of cherry layer thickness showed significant ($P \leq 0.05$) differences for cup acidity (Table 17). At Gomma-1, drying coffee variety 744 and74110 on bricks floor using layer thickness loads of 20 to 30 kg/m^2 and variety 744+74110 with loads of 20 to 30kg/m^2 produced the highest mean acidity values (12.00) and variety 744, 74110 and 744+74110 dried on raised beds covered with bamboo mats and mesh wire using the density loads of 20 to 40 kg/m^2 exhibited the highest mean acidity values, which were detected to be moderately pointed acidity. Moreover, statistically similar results were recorded on the interactions at Gomma-2 and Kossa.On the other hand; the treatment combinations of variety 744+74110; 744 and 74110 drying on bricks floor using the density levels of 40kg/m^2 treated as the conventional farmers practice and variety 74110 and 744+74110 dried on raised beds covered with bamboo mats and mesh wire using the farmers practice across location resulted in the lowest mean acidity values (9.00) detected as medium acidity. The overall mean cup acidity value scored (11.34) and detected to be moderately pointed acidity.

This result could be attributed to differences among locations for environmental factors, such as rain fall and altitudes, the structure of processing materials, the genetic characteristics of varieties and levels of cherries layer thickness. Processing coffee on bricks floor and both raised beds covered with bamboo mats and mesh wires using layer thickness levels of 20 to 40kg/m^2 induced good and desirable cup acidity and was detected as good acidity. The conventional practice brought further fermentation and mould development which might have affected the acidity in the beans and resulted in medium acidity. The findings of Mawardi (2005) and Drinnan (2007a) have also indicated that, because of very poor preparations, dry processed coffee has low aroma, flavour and acidity. Similarly, Brollo et al. (2008) reported that acidity is an important sensory attribute of coffee brews influenced by several factors: mainly coffee variety, processing method, and country of origin.

Table 15. Interaction effects among locations, drying materials, and variety and layer thicknesses on coffee brew cup acidity quality of dry processed coffee

Location	**Drying Materials**	**Variety by Layer thickness (kg/m^2)**											
		744				**74110**				**744 + 74110**			
		20	**30**	**40**	**Conv (40)**	**20**	**30**	**40**	**Conv (40)**	**20**	**30**	**40**	**Conv (40)**
Goma -1	Bricks	12.00^{a}	12.00^{a}	11.00^{ab}	10.00^{bc}	12.00^{a}	12.00^{a}	11.00^{ab}	9.00^{c}	12.00^{a}	12.00^{a}	10.00^{bc}	12.00^{a}
	Bamboo Mat	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}
	Wire Mesh	12.00^{a}	12.00^{a}	12.00^{a}	11.00^{ab}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}
Goma -2	Bricks	12.00^{a}	11.00^{ab}	11.00^{ab}	9.00^{c}	12.00^{a}	11.00^{ab}	9.00^{c}	9.00^{c}	12.00^{a}	10.00^{bc}	11.00^{ab}	10.00^{bc}
	Bamboo Mat	12.00^{a}	11.00^{ab}	12.00^{a}	11.00^{ab}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}
	Wire Mesh	12.00^{a}	12.00^{a}	12.00^{a}	9.00^{c}	12.00^{a}	12.00^{a}	12.00^{a}	9.00^{c}	12.00^{a}	12.00^{a}	11.00^{ab}	9.00^{c}
Kosa	Bricks	12.00^{a}	11.00^{ab}	9.00^{c}	9.00^{c}	11.00^{ab}	12.00^{a}	12.00^{a}	10.00^{bc}	11.00^{ab}	12.00^{a}	10.00^{bc}	9.00^{c}
	Bamboo Mat	11.00^{ab}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}
	Wire Mesh	12.00^{a}	11.00^{ab}	12.00^{a}	10.00^{bc}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	12.00^{a}	10.00^{bc}	12.00^{a}	12.00^{a}
LSD ($P \leq 0.05$)	1.742												
CV (%)	8.05												

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

4.5.3. Body

The four ways interaction among factors was not significant but the interactions among drying materials, variety and cherry layer thickness showed significant differences ($P \leq 0.05$) for cup body. It was observed that 20kg/m^2 of cherry loads of variety 744 dried on bricks floor, variety 74110 and 744+74110 dried on bamboo mats and variety 744 and 74110 on mesh wire, and 30 kg/m^2 of variety 74110 on bamboo mats resulted in significantly higher mean cup body (Table 18), which was identified as moderately full body**.** On the other hand, the lowest cup body was revealed on variety 744 which was dried on bricks floor, with the density level of 30 to 40kg/m^2 and in the conventional practice. Similarly, variety 744, 74110 and 744+74110 dried on bamboo mats using the density levels of 40kg/m^2 and in the conventional practice and variety 744 dried on raised beds covered with mesh wire using the density levels of 40kg/m^2 and the conventional practice scored in statistically similar and lowest mean cup body values detected to be medium body. The average cup body value was 9.96 and detected as medium body.

From the result observed in the present study it can be identified that as the cherry layer thickness increased the degree of mouth fullness of the body becomes lower indicating that there exist variations among drying methods and varieties. Hence, one can understand that when coffee dried on bamboo mats with the average cherry density of 20 to 30kg/m^2 it induces moderately full cup body. While, coffee dried on bricks and mesh wire with thick density levels produced medium body quality. Similar findings have been reported by Musebe et al. (2007), indicating that sun-drying of Arabica coffee on raised beds is advantageous for improved quality. The results of the present study were also in agreement with the findings of Yigzaw (2005) who reported that there is variation in cup body among genotypes of *Coffea arabica*, identifying suitability of acidity and body as selection criteria for genetic improvement of overall liquor quality. In line with this, Prodolliet (2004) reported that dry processed coffee produces a beverage with a strong aroma, moderate acidity, strong body and natural sweetness**.** Bacon (2005) has also reported that, since it is always dried in contact with its mucilage, dry processed coffee has less aromatic but a better body. As reported by Negussie et al. (2007), properly dry processed coffee has balanced and good acidity, body and flavour and can attain higher grades.

Table 16. Effects of interaction among drying materials, variety and layer thickness on cup body quality of coffee bean

Drying Material	**Variety**	**Levels of Layer Thicknesses (kg/m^2)**			
		20	**30**	**40**	**40 (conv.)**
Bricks	744	11.33^{abc}	9.66^{fgh}	9.00^{h}	9.00^{h}
	74110	10.66^{cde}	10.33^{def}	9.33^{gh}	9.00^{h}
	744+74110	10.33^{def}	10.00^{efg}	9.00^{h}	9.00^{h}
Bamboo mats	744	10.66^{cde}	11.00^{bcd}	9.33^{gh}	9.33^{gh}
	74110	11.66^{ab}	11.33^{abc}	10.33^{def}	9.00^{h}
	744+74110	12.00^{a}	11.00^{bcd}	10.00^{efg}	9.00^{h}
Mesh wire	744	11.33^{abc}	10.00^{efg}	9.66^{fgh}	9.00^{h}
	74110	11.66^{ab}	9.00^{h}	9.33^{gh}	9.33^{gh}
	744+74110	10.33^{def}	9.00^{h}	9.66^{fgh}	9.00^{h}
LSD (5%)			0.977		
CV (%)			10.54		

Figure followed by the same letter(s) are not significantly different at P≤0.05

The two way interaction between location and coffee variety showed significant variations (P≤0.05) for cup body of coffee samples. Accordingly, at Kossa variety 74110 produced the maximum mean body value (10.41) detected as medium to moderately full body. Also, variety 744 at Gomma-1 and the mixture of 744+74110 at Kossa revealed statistically identical and maximum mean body values. While, at Gomma-1, variety 74110 and 744+74110 and at Gomma -2, variety 744 and 744+74110 and at Kossa, variety 744 showed the least mean cup body values ranging between 9.58 to 9.91 , and detected to be medium body score.

This could be associated to the combined effect of the environment, climatic conditions such as temperature and rainfall and the genetic characteristics of the varieties. Coffee variety 744 is highly suitable at lower altitude, while variety 74110 is highly suitable at higher altitude and produces better quality with considerable body. This finding is in line with that of Yigzaw (2005) and Avelino et al. (2005), indicating that provided other factors are kept constant, better quality coffee can be produced at higher altitudes, while lowland coffees are somewhat bland, with considerable body. Beverage quality is, therefore, partly determined by environmental factors. Furthermore, Emerson et al. (2005) and Borovikovskaya (2007) have reported that most of the best quality coffee is growing in the high mountain regions, linking up with the topography and annual precipitation, and the production of good quality coffee beans in specific areas is characterized by their climatic conditions. This clearly shows that the climate is an important factor in determining the quality of coffee beverage (acidity, body and flavour).

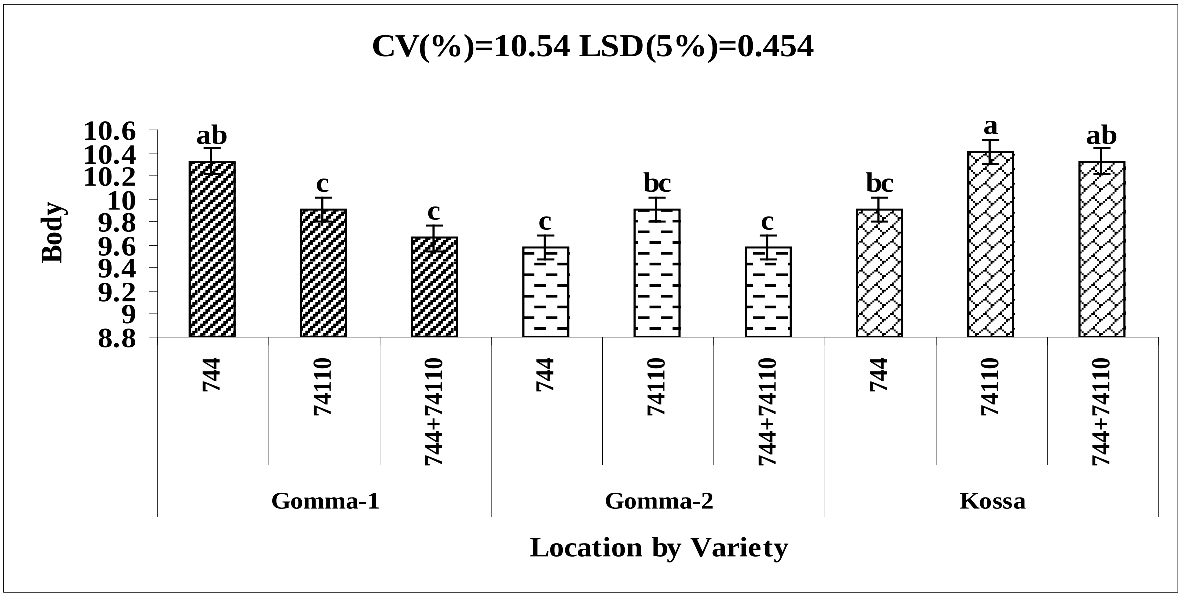


Figure 4. Interaction effects between location and variety on coffee brew cup body quality of dry processed coffee

Bars capped by the same letter(s) are not significantly different at P≤0.01

4.5.4. Flavour

Flavour, an overall test of the brew, is the combination of body and acidity evaluated during the cup analysis. Accordingly, the four way and two way interactions were non significant (P≥0.05). However, the flavour quality revealed significant differences (P≤0.05) among the three way interaction effects of location, sun-drying methods and density levels of the cherries (Table 19). At Gomma-1, coffee dried on raised beds covered with bamboo mats using the layer thickness load of 20kg/m^2 scored the highest mean flavour value (11.33) and was detected to be average to fairly good flavour. On the contrary; at Gomma-1 and Gomma-2, coffee dried on bricks floor with loads of 20 to 40kg/m^2 and the conventional practice and drying coffee on raised beds covered with bamboo mats and mesh wires using the layer thickness loads of 30 to 40kg/m^2 and the conventional practice resulted in the lowest mean cup flavour values ranging from 9.00 to 9.33 and induced average flavour. Similarly; at Kossa, coffee dried on bricks floor and raised beds covered with mesh wires with loads of 20 to 40kg/m^2 and the conventional practice and drying coffee on raised beds covered with bamboo mats using the layer thickness loads of 40kg/m^2 and the conventional practice resulted in the lowest mean cup flavour values detected to average flavour.

As a result, processing coffee on raised beds covered with bamboo mats using thin layer thicknesses induced better flavour. While, bricks floor in contact with soil and the sagging nature of mesh wire in combination with thick layered cherries induced off-flavours and resulted in less flavour quality. The present finding supports the results of Subedi (2010), who reported that coffee dried on bricks floor in contact with soil becomes dirty and blotchy, resulting into dull aroma and earthy flavour in the beverage. Furthermore, Negussie et al. (2009) and Drinnan (2007b) have reported that properly processed coffee has balanced and good acidity, body and flavour. The influence of processing style on the quality and flavour of coffee has also been elaborated by Endale (2008) who reported that coffee with a better attention turn out to have a better flavour.

Table 17. Interaction effect of locations, drying materials and layer thicknesses on brew cup flavour quality of coffee bean

Location	**Drying Materials**	**Levels of Layer Thicknesses (kg/m^2)**			
		20	**30**	**40**	**40(conv.)**
Gomma-1	Bricks	9.33^{cd}	9.00^{d}	9.00^{d}	9.00^{d}
	Bamboo mats	11.33^{a}	9.00^{d}	9.00^{d}	9.00^{d}
	Mesh wire	9.66^{bc}	9.00^{d}	9.00^{d}	9.00^{d}
Gomma-2	Bricks	9.00^{d}	9.00^{d}	9.00^{d}	9.00^{d}
	Bamboo mats	9.66^{bc}	9.00^{d}	9.00^{d}	9.00^{d}
	Mesh wire	10.00^{b}	9.00^{d}	9.00^{d}	9.00^{d}
Kossa	Bricks	9.33^{cd}	9.66^{bc}	9.33^{cd}	9.00^{d}
	Bamboo mats	10.00^{b}	10.00^{b}	9.33^{d}	9.00^{d}
	Mesh wire	9.00^{d}	9.00^{d}	9.00^{d}	9.00^{d}
LSD (5%)		0.633			
CV (%)		7.36			

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

Similarly; cup flavour, reflected by the overall test of the brew, showed significant ($P \leq 0.05$) differences for the three way interactions of location, variety and cherry layer thicknesses (Table 20). At Gomma-1, variety 744 exhibited the highest flavour quality. Similarly; at Gomma-2, variety 74110 using the layer thickness of 20kg/m^2 and at Kossa, variety 744 with the layer thickness load of 30kg/m^2 produced statistically similar and the highest flavour quality values (10.00 to 10.66) and detected as average to fairly good flavour. On the contrary; at Gomma-1, coffee variety 744, 74110 and 744+74110 dried using the density levels of 30 and 40kg/m^2 the conventional practice exhibited the lowest mean flavour values ranging from 9.00 to 9.33 and detected to be average flavour score. Moreover, at Gomma-2 and at Kossa, variety 744 and 744+74110 dried using the density levels of 20 to 40kg/m^2 and the conventional practices and the variety 74110 using the density levels of 30 to 40kg/m^2 and the conventional practice had scored statistically similar and the lowest mean flavour values and detected to be average flavour quality score.

Appropriate post harvest management practice using thin layer thickness could improve the flavour quality of dry processed coffee. Whereas, the thick layered cherries induced off-flavours of the green coffee beans. The present finding agrees with the report of Endale (2008) who reported that coffee with a better attention and continuous stirring resulted in a better flavour. Prodolliet **(**2004) and FAO (2010) also reported that natural coffees present strong body and aroma, mildly acidity and sweet flavour. Coffee beans grown at medium to higher elevations tend to be denser, larger, and have better flavour. Negussie et al. (2009) also reported that properly processed coffee is free of off-flavour and has balanced and good acidity, body and flavour. In addition, Wintgens (2004) indicated that beans produced at low altitude have a negative effect on the flavour and the structure of the fruits due to accelerated maturation. Furthermore, Drinnan (2007b) reported that processing style has a large influence on the quality and flavour of coffee.

Table 18. Interaction among location, variety and layer thicknesses for brew cup flavour quality of green coffee bean

Location	Variety	Levels of Layer thicknesses (kg/m^2)			
		20	30	40	40 (conv)
Gomma-1	744	10.66[a]	9.00[e]	9.00[e]	9.00[e]
	74110	9.66[cd]	9.00[e]	9.00[e]	9.00[e]
	744+74110	10.00[bc]	9.00[e]	9.00[e]	9.00[e]
Gomma-2	744	9.33[de]	9.00[e]	9.00[e]	9.00[e]
	74110	10.33[ab]	9.00[e]	9.00[e]	9.00[e]
	744+74110	9.00[e]	9.00[e]	9.00[e]	9.00[e]
Kossa	744	9.33[de]	10.00[ab]	9.00[e]	9.00[e]
	74110	9.33[de]	9.66[cd]	9.66[cd]	9.00[e]
	744+74110	9.66[cd]	9.33[de]	9.00[e]	9.00[e]
LSD (5%)			0.633		
CV (%)			7.36		

Figures followed by the same letter(s) are not significantly different at P≤0.05

4.5.5. Total cup quality

The four way and two ways interaction effects were found to be non-significant. While, the total cup quality revealed significant *(P≤0.05)* variations among the three way interaction of location, sun drying method and coffee variety (Table 21). Consequently, at Kossa, variety 74110 dried on raised beds covered with bamboo mats exhibited the highest mean total cup quality value (47.75). Also, at Gomma-1, variety 744 and 744+74110 dried on raised drying beds covered with bamboo mats and mesh wire revealed statistically identical and the highest mean total cup quality values ranging 46.50 to 47.25. At Gomma-2, variety 74110 and at Kossa variety 744, 74110 and 744+74110 dried on bamboo mats produced statistically similar total cup quality values ranging between 47.00 and 47.25. On the other hand, at Kossa, variety 744 dried on bricks floor scored the lowest mean total cup quality values (42.75). Also; at Gomma-2, variety 744, 74110 and 744+74110 dried on bricks floor exhibited statistically identical and the lowest mean total cup quality values ranging from 43.00 to 44.00. The overall mean total cup quality value was (45.35).

This could be probably because of the nature of drying materials, as bamboo mats and mesh wire might have favoured better air movement and thus minimized the rate of fermentation and induced enough dehydration that could enhance to maintain the inherent quality attributes of coffee beans. On the contrary, bricks floor exposed to undesirable elements favoured further fermentation and rewetting, and eventually deteriorated the cup quality attributes of coffee.

The present finding agrees with the report of Yigzaw (2005) who stated that provided other factors are kept constant, better quality coffee can be produced at high altitudes. Avelino et al. (2005) and Borovikovskaya (2007) have also reported that most of the best quality coffee is growing in the high mountain regions linking up with the topography and annual precipitation, and the beverage quality is, therefore, partly determined by environmental factors. The present finding also agrees with the findings of Musebe et al. (2007) and ICO (2010) indicating that improved sun-drying coffee on raised beds is advocated for improved quality. Furthermore, Anwar (2010) reported that coffee drying by using raised bed with mesh wire, wooden and bamboo mats would result in better quality. Subedi (2010) also reported that coffee dried on bricks floor in contact with soil becomes dirty and blotchy, resulting in dull aroma and earthy flavour. Similar findings were reported by Van der Vossen (1985), indicating that there exist significant differences among different Arabica coffee cultivars for cup quality attributes.

Table 19. Interaction among location, drying method and variety for total cup quality score value of unwashed Arabica coffee

Location	**Drying Materials**	**Variety**		
		744	**74110**	**744+74110**
Gomma-1	Bricks	45.50cdef	44.50efgh	45.00defg
	Bamboo mats	47.25ab	45.50cdef	46.50abcd
	Mesh wire	46.50abcd	45.75bcde	44.75efg
Gomma-2	Bricks	44.00fghi	43.00hi	43.75ghi
	Bamboo mats	44.75efg	47.00abc	45.75bcde
	Mesh wire	44.75efg	45.00defg	44.00fghi
Kossa	Bricks	42.75i	46.00bcde	44.50efgh
	Bamboo mats	47.00abc	47.75a	47.25ab
	Mesh wire	44.75efg	45.75bcde	45.50cdef
LSD (5%)		1.853		
CV (%)		4.39		

Figures followed by the same letter(s) are not significantly different at $P \leq 0.05$

Similarly, sensory evaluation depicted in Table 17 showed significant (*$P \leq 0.05$)* variations among the interactions of location, drying materials and levels of layer thicknesses. Accordingly; at Gomma-1, coffee dried on raised beds covered with bamboo mats using the density levels of 20kg/m^2 scored the highest mean total cup quality value (50.00). Also, the combination of bamboo mats with layer thickness loads of 30kg/m^2 at Kossa, produced statistically identical and the highest mean cup acidity value(49.00). On the other hand; at Gomma-2, coffee dried on bricks floors and raised beds covered with mesh wire and at Kossa, coffee dried on bricks floor using the density levels of 40kg/m^2 in the conventional practice resulted the lowest mean total cup quality values ranging from 40.00 and 41.00, respectively. The average mean total cup quality value was (45.35).

This could be due to high temperature effect at Gomma-1(lowland) and ambient air movement on bamboo mats contributed to minimize further fermentation and induced better cup quality. In general, provided that other factors are kept constant, dry processing using raised beds covered with bamboo mats and mesh wires using thin layer thicknesses improved cup quality characteristics. Appropriate layer thicknesses on raised beds might have induced ample air movement and prevented uneven drying and enhanced coffee quality. On the contrary, bricks floors exposed to undesirable elements favoured further fermentation which in turn deteriorated the cup quality attributes. The present study agrees with the findings of ICO (2010) and Musebe et al. (2007) who confirmed that improved sun-drying using raised beds is advantageous for improved quality. Anwar (2010) also reported that coffee drying by using raised bed with mesh wire and bamboo mats have resulted in better quality. Furthermore, Solomon and Behailu (2006) also reported that higher heaps may result in admixture of under and over dried beans and unevenly heaped coffee yields inferior cup quality.

Table 20. Interaction among location, drying materials and layer thickness for total cup quality score values of unwashed Arabica coffee

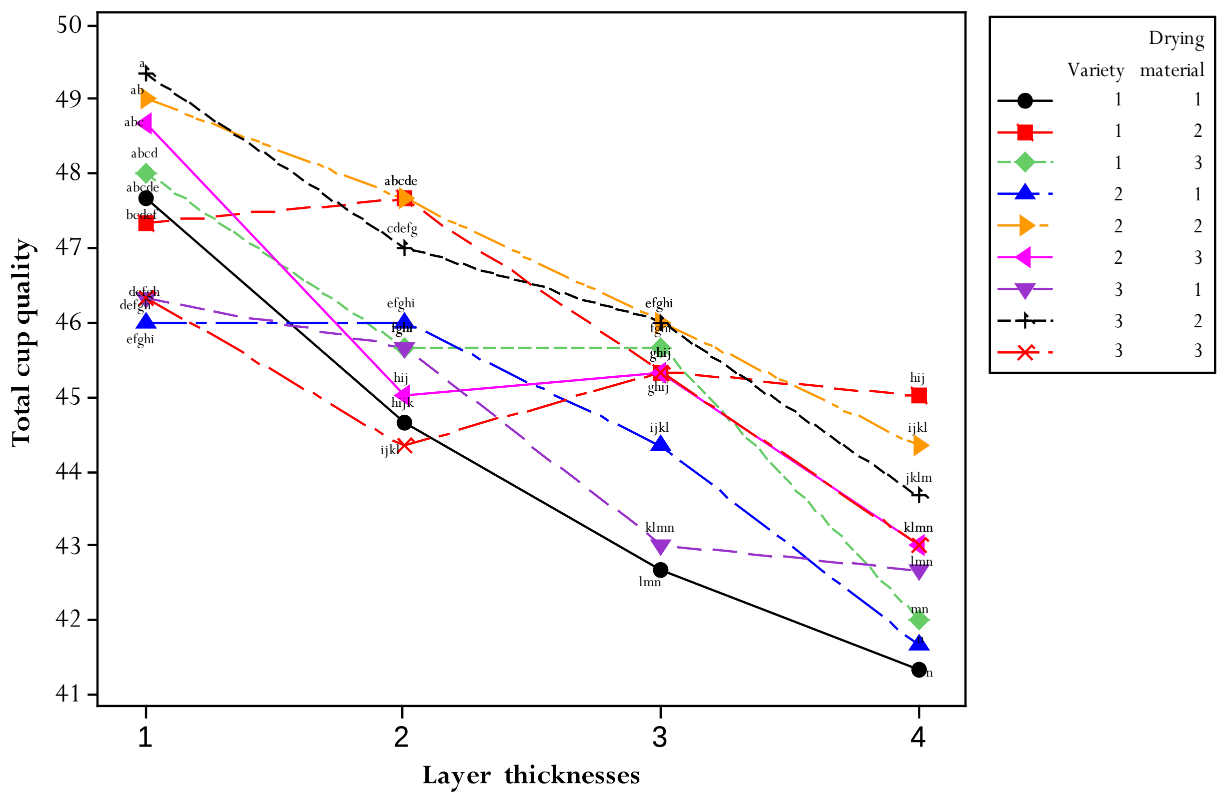
Location	Drying Materials	Levels of Layer Thicknesses (kg/m^2)			
		20	30	40	40 (conv.)
Gomma-1	Bricks	47.33^{bcdef}	45.66^{fghijk}	43.66^{lmn}	43.33^{mn}
	Bamboo mats	50.00^{a}	47.00^{cdefg}	45.00^{hijklm}	43.66^{lmn}
	Mesh wire	48.00^{bcd}	45.00^{ghijkl}	46.00^{efghij}	43.33^{mn}
Gomma-2	Bricks	46.33^{defghi}	43.66^{lmn}	43.33^{mn}	41.00^{o}
	Bamboo mats	47.66^{bcde}	46.00^{efghij}	45.66^{fghijk}	44.00^{klmn}
	Mesh wire	48.33^{abc}	45.33^{ghijkl}	44.66^{ijklmn}	40.00^{o}
Kossa	Bricks	46.33^{defghi}	47.00^{cdefg}	43.00^{n}	41.00^{o}
	Bamboo mats	48.00^{bcd}	49.00^{ab}	46.66^{cdefgh}	45.33^{ghijkl}
	Mesh wire	46.66^{cdefgh}	44.33^{jklmn}	45.66^{fghijk}	44.66^{ijklmn}
LSD(5%)				1.853	
CV (%)				4.39	

Figures followed by the same letter(s) are not significantly different at P≤0.05

Furthermore; the results of sensory evaluation presented in Fig.4 showed significant (P≤0.05) variations among the three way interaction of drying methods, variety and levels of layer thickness for total cup quality of green coffee. Variety 74110 and 744+74110 dried on raised beds covered with bamboo mats using the layer thickness loads of 20kg/m^2 exhibited the highest mean total cup quality value (49.33). Similarly, variety 744 and 74110 dried on raised beds covered with mesh wire resulted statistically similar and the highest mean total cup quality value (48.00). On the other hand, variety 744 and 74110 dried on bricks floor using the layer thickness loads of 40kg/m^2 treated in farmers' practice scored the lowest mean total cup quality value (41.33). Also, variety 744 dried on raised beds covered with mesh wire resulted in statistically similar and the lowest mean total cup quality value (42.00).

This could be due to the structure of the drying materials; the inherent characteristics of the variety and the level of the layer thickness having influence on total cup quality. The raised beds covered with bamboo mats and mesh wire using thin layer thickness loads of cherries might have induced better aeration to induce enough dehydration and thus, contributed to improved total cup quality. On the contrary, the thick layered cherries exposed to further fermentation and slow rate of dehydration induced to develop mould development and quality deterioration. The findings of the present work agrees with the findings of Musebe et al. (2007) and ICO (2010), indicating that sun-drying on raised bed is an effective method to produce improved high quality coffee.

Wintgens (2004) and Yigzaw (2005) also pointed out the presence of genetic variability among Ethiopian coffee selections for green bean physical characteristics and cup quality attributes. The result of the present work was supported by the findings of Antonym and Surip (2010) who reported that natural coffee processing can produce high quality coffee and creates a highly preferred coffee, compared to full wash, indicating that processing does have an identifiable influence on cup taste.



LSD (*P≤0.05)=1.853*   *CV(%)=4.39*

Figure 5. Interaction effects among drying materials, variety and layer thickness on total cup quality of unwashed Arabica coffee

Bars capped by the same letter(s) are not significantly different at P≤0.01

**Variety; 1=744;2=74110 and 3=744+74110*
**Drying materials:1=bricks;2=bamboo mats and 3=mesh wire*
*Layer thickness: 1=20kg/m^2; 2=30kg/m^2; 3=40kg/m^2 and 4=40kg/m^2 (conventional system)

4.6. Total Coffee Quality

The four way interaction effects among location, sun drying methods, coffee variety and levels of cherry layer thickness showed significant *($P \leq 0.05$)* variations for total quality attributes of coffee beans (Table 23). Accordingly; at Gomma-2, coffee variety 74110 processed on raised drying beds covered with mesh wire using the layer thickness loads of 20kg/m^2 resulted in the highest mean total quality value (88.00). Also; at Gomma-1,variety 744, scored total coffee quality (85.00) and at Kossa, variety 744 and 74110 dried on bamboo mats using the layer thickness loads of 30 and 20kg/m^2 produced total coffee quality (86.00) and the highest mean total quality value ranging between (*85*-89.99) were detected as excellent specialties taste, received a "specialty grade 1" classification and profiled under grade 2. Similarly, at Gomma-1 variety 74110 and 744+74110 dried on bamboo mats using the layer thickness loads of 20kg/m^2 scored total coffee quality values (81.00 and 84.00) and at Gomma-2, variety 74110 and 744+74110 dried on bamboo mats using the layer thickness loads of 20kg/m^2 produced total coffee quality values ranging from 81.00 to 84.00. Variety 744 and dried on raised drying beds covered with mesh wire using loads of 20 and variety 744+74110 with layer thickness of 20 to 30 kg/m^2 resulted in total coffee quality values ranging between 80.00 and 84.00. Further more; at Kossa, variety 744, 74110 and 744+74110 dried on bamboo mats using the layer thickness loads of 20 and 20 to 40 kg/m^2 exhibited total coffee quality values ranging from 81.00 to 84.00. These values ranging in between (*80*-84.99) were detected as very good specialties taste, received a "specialty grade 2" classification and profiled under grade 2.On the other hand; at Gomma-2, variety 744, 74110 and 744+74110 dried on bricks floor with the density levels of 30kg/m^2 to 40kg/m^2 and the conventional practice scored statistically similar and the lowest mean total quality values ranging 58.83 to 61.16. The total coffee quality values detected below specialty coffee quality were identified as commercial grade classifications with specified categories of 58.00-62.00 profiled under grade 5. The mean total coffee quality score value was 73.47 and, thus, profiled under grade 3.

This could be due to the combined effect of variability among locations, structure of the drying materials; the genetic characteristics of the variety and the level of the layer thickness have influence on total quality attributes of coffee beans. In general; at higher altitudes, properly processed coffee dried on raised beds covered with bamboo mats with the layer thickness loads of 20 to 30kg/m^2 and at low, mid and high altitudes on mesh wire with loads of 20kg/m^2 due to appropriate fermentation and enough dehydration resulted in high total coffee quality and classified as specified categories of (*85*-89.99) which can attain excellent and very good specialty taste (80-84.99) and received a “specialty grade 1 and 2” classification profiled under grade 2. Whereas, the farmers’ conventional system and thick layered cherries induced intermixing and re-wetting of cherries due to further fermentation and slow rate of dehydration caused quality deterioration, thus identified as commercial grade classifications profiled under grade 3 to 6.

.

These results are in agreement with the findings of Avelino et al. (2005) and Yigzaw (2005) reported that, beverage quality is partly determined by environmental factors. Similarly, this result also agrees with the findings of Mekonnen (2009) the sun dried coffee on raised beds with mesh wire following appropriate management had a good physical and over all cup quality with a value of 84.25. Furthermore, Negussie et al. (2009) have indicated that sun dried coffee on raised beds following appropriate management had a good physical and over all cup quality. Silvano (2004) also reported that drying coffee on bricks terraces, favours the development of micro organisms on the surface of cherries increases respiration rate, accelerates the fermentation process and facilitates deterioration. Van der Vossen (1985) has also reported that there exist significant differences among Arabica coffee cultivars for cup quality attributes. JARC (1996) also reported that variety 744 is highly suitable in the mid altitude and suitable both in lowland and highland areas; while, variety 74110 is highly suitable in highland areas and suitable in mid altitudes maintaining commercially acceptable quality. Results of the present study are in agreement with the findings of FAO (2002) and Appropedia (2010) , indicating that a good quality finished dry processed product can only be obtained through the application of appropriate and scientifically tested practices and proper management. Furthermore, Antonym and Surip (2010) have reported that the dry coffee processing can produce high quality coffee and creates a highly preferred coffee compared to full wash indicating that processing does have an identifiable influence on cup taste. The dry processing coffee if consistent quality control is applied to dry processing, the resulting coffee would be highly preferred by the specialty coffee industry.

Table 21. Interaction effects among location, drying method, variety and layer thickness on total coffee quality

Location	Drying Materials	Variety by Layer thickness (kg/m^2)											
		744				74110				744 + 74110			
		20	30	40	conv (40)	20	30	40	conv (40)	20	30	40	conv (40)
Goma-1	Bricks	76.50^{ijkln}	72.50^{pqrstuv}	71.83^{pqrstuvwxy}	66.16 (\)^-`ab	76.50^{ijkln}	75.00^{klmnop}	69.16 wxyz(\)	66.16 (\)^-ab	77.50^{hijkl}	75.50^{jklmnop}	68.83wxyz(\)	69.50^{vwxyz}
	Bamboo mat	85.00^{abc}	75.50^{klmnop}	74.00^{lmnopqr}	72.00^{pqrstuvwx}	81.33^{cdef}	74.50^{klmnopr}	70.00^{uvwxy}	67.50 z(\)^-a	84.00^{bcd}	73.50^{mnopqrt}	72.50^{pqrstuv}	68.16 yz(\)^-`
	Wire mesh	84.00^{bcd}	82.00^{cdef}	75.00^{klmnopq}	70.50^{stuvwxyz}	83.00^{bcde}	75.00^{klmnop}	74.00^{lmnopqs}	67.50 z(\)^-a	79.00^{fghij}	76.00^{jklmno}	73.50^{mnopqrstu}	68.83wxyz
Goma-2	Bricks	73.50^{nopqrsu}	65.16 ^-`abc	63.16^{bcd}	59.16^{e}	64.83 -bcd	61.16^{de}	58.83^{e}	59.16^{e}	72.33^{pqrstuw}	63.83^{abcd}	63.16^{bcd}	61.50^{cde}
	Bamboo mat	73.00^{opqrstuv}	71.50^{rstuvwx}	74.00^{lmnopqr}	69.83^{uvwxyz}	84.00^{bcd}	72.50^{opqrstu}	75.50^{klmnopq}	70.16t^{uvwx}	81.00^{defgh}	74.00l^{mnopqr}	70.83^{stuvwxy}	68.83^{wxyz}
	Wire mesh	84.00^{bcd}	75.00^{klmnop}	72.00^{pqrstuvwx}	63.83^{abcd}	88.00^{a}	74.00^{lmnopqr}	74.50^{klmnpoqr}	65.83 \)^-`ab	82.00cdef	80.00^{efghi}	70.50^{tuvwxyz}	67.50 z^-`a
Kosa	Bricks	73.50^{nopqrsT}	68.50 xyz(\)^-	64.50 `abcd	63.50^{bcd}	77.00^{ijk}l	75.50^{jklmnop}	69.16^{wxyz}	68.83^{wxyz}	73.83^{mnopqrt}	71.^{16rstuvwxz}	65.50 ^{ab}	64.50 `abcd
	Bamboo mat	83.00^{bcde}	86.00^{ab}	74.50^{klmnopr}	75.00^{klmnopq}	86.00^{ab}	84.00^{bcd}	82.00cdef	78.00^{ghijk}	82.00^{cdef}	82.00^{cdef}	82.00^{cdef}	71.50qrstuvw
	Wire mesh	75.00^{klmnopq}	74.00^{lmnopq}	74.00^{lmnopqr}	70.00^{uvwxyz}	81.00^{defg}	80.00^{efghi}	78.00^{ghijk}	78.00^{ghijk}	78.00^{ghijk}	77.00^{ijklm}	73.50^{mnopqrt}	76.00^{jklmno}
LSD (5%)	3.671												
CV (%)	3.10												

Figures followed by the same letter(s) are not significantly different at P≤0.05

4.7. Coffee Grading

The four way interaction showed significant differences (*$P \leq 0.05$)* for grade of unwashed coffee at the study sites (Table 24). At Gomma -1,variety 744, 74110 and 744+74110 dried on raised beds covered with bamboo mats using the density level of 20kg/m^2 resulted in statistically similar and the highest grading score values ranging from 2.00 to 2.33 and profiled under grade 2. Variety 744 and 74110 dried on mesh wire using the density levels of 20 to 30 kg/m^2 and 20 kg/m^2 also produced the highest grading score profiled under grade 2. However, variety 744, 74110 and 744+74110 dried on bricks floor using the density levels of 40kg/m^2 treated as the conventional system and variety 74110 and 744+74110 dried on both drying beds covered with bamboo mats and mesh wire using the layer thickness loads of 40kg/m^2 treated as the conventional system revealed statistically similar and the lowest grading score (3.66 to 4.00) and profiled under grade 4. Similarly ; at Gomma-2, coffee variety 74110 and 744 +74110 dried on raised beds covered with bamboo mats and mesh wire using the density level of 20kg/m^2 and variety 744 dried on raised beds covered with mesh wires with the density levels of 20 kg/m^2 produced the highest grading score (2.00) profiled under grade 2. On the other hand; variety 744, 74110 and 744+74110 dried on bricks floor using density levels of 30 to 40kg/m^2 and treated as the conventional practice scored in statistically identical at part and the lowest mean grade score ranging from 5.00 to 5.66 and profiled under the grade 5 and 6.

Furthermore; at Kossa, variety 744 dried on raised beds covered with bamboo mats using the density level of 20 and 30kg/m^2 exhibited significantly higher grade score ranging between 2.00 to 2.33 and profiled under grade 2. Variety 74110 and 744+74110 dried on raised beds covered with bamboo mats using the layer thickness of 20 to 40kg/m^2 and variety 74110 dried on raised beds covered with mesh wires using the density levels of 20 kg/m^2 had also resulted in statistically similar and the highest grading score profiled under grade 2. However; variety 744 and 744+74110 dried on bricks floor using density levels of 30 to 40kg/m^2 and treated as the conventional practice scored in statistically identical and the lowest mean grade values (3.66 to 4.00) and profiled under the grade 4.

These observations could be associated with the nature of drying materials, as drying tables covered with bamboo mats and mesh wire provide protection of the crop from re-wetting because the open lower surface enhanced appropriate fermentation and enough dehydration resulting in better quality grades. However, the farmers' conventional systems induce intermixing and re-wetting of cherries and, thus quality deterioration.

This result is in line with Yigzaw (2005) who has reported that better quality coffee can be obtained from high altitudes. Anwar (2010) has also indicated that dry processing coffee by using raised bed with mesh wire and bamboo mats produced better quality. While, the conventional way of coffee processing at Gomma and Manna woredas resulted in lower grade 4 ,and 3, respectively. Furthermore, the result of this study was in agreement with the finding of Mekonnen (2009) and Beza (2010) who have reported that coffee varieties dried on raised beds following appropriate management had a good physical and over all cup quality and variety 74110, dry processed on mesh wire and bamboo mats was profiled under grade 2. Subedi (2010) has also reported that drying coffee on bricks floor in contact with soil has a great influence on its aroma and flavour. Negussie et al. (2009) have confirmed that properly processed coffee having balanced and good acidity, body and flavour can attain higher grades. The result of the present study is also in line with findings of Yigzawu (2005) , indicating the presence of genetic variability among Ethiopian coffee selections for green bean physical characteristics and cup quality attributes. The present findings also support the report of JARC (1996), indicating that coffee variety 74110 is highly suitable at medium and high altitudes to attain its maximum commercially acceptable quality. Similar results has been reported by Bhawan and East Arjun (2006) and ICO (2010), indicating that for coffee drying under good ambient conditions the thinner the layer the earlier to drying and producing high quality coffee. Moreover, the structure of the drying facilities has also a great influence on coffee quality profile. Since the comparative sensorial tests as described by ECX (2009), are evaluated based on 1 to 9 scales, where 9 corresponded to the worst cup and 1 to the best cup. The coffee grades observed in the present study could be considered as of better quality.

Table 22. Interaction effects among location, drying methods, variety and layer thickness on quality score of unwashed coffee grade

Location	**Drying Materials**	**Variety by Layer Thickness**											
		744				**74110**				**744 + 74110**			
		20	**30**	**40**	**Conv (40)**	**20**	**30**	**40**	**Conv (40)**	**20**	**30**	**40**	**Conv (40)**
Goma-1	Bricks	3.00^{fg}	3.00^{fg}	3.33^{ef}	4.00^{cd}	3.00^{fg}	3.00^{fg}	3.66^{de}	4.00^{cd}	3.00^{fg}	3.00^{fg}	3.66^{de}	4.00^{cd}
	Bamboo Mat	2.00^{i}	3.00^{fg}	3.00^{fg}	3.00^{fg}	2.33^{hi}	3.00^{fg}	3.33^{ef}	4.00^{cd}	2.00^{i}	3.00^{fg}	3.00^{fg}	4.00^{cd}
	Wire Mesh	2.00^{i}	2.00^{i}	3.00^{fg}	3.33^{ef}	2.00^{i}	3.00^{fg}	3.00^{fg}	4.00^{cd}	3.00^{fg}	3.00^{fg}	3.00^{fg}	4.00^{cd}
Goma-2	Bricks	3.00^{fg}	4.00^{cd}	4.33^{c}	5.00^{b}	4.00^{cd}	5.00^{b}	5.66^{a}	5.33^{ab}	3.00^{fg}	4.33^{c}	4.33^{c}	5.00^{b}
	Bamboo Mat	3.00^{fg}	3.33^{ef}	3.00^{fg}	3.66^{de}	2.00^{i}	3.00^{fg}	3.00^{fg}	3.66^{de}	2.33^{hi}	3.00^{fg}	3.33^{ef}	4.00^{cd}
	Wire Mesh	2.00^{i}	3.00^{fg}	3.00^{fg}	4.33^{c}	2.00^{i}	3.00^{fg}	3.00^{fg}	4.00^{cd}	2.33^{hi}	2.66^{gh}	3.33^{ef}	4.00^{cd}
Kosa	Bricks	3.00^{fg}	4.00^{cd}	4.00^{cd}	4.00^{cd}	3.00^{fg}	3.00^{fg}	3.66^{de}	4.00^{cd}	3.33^{ef}	3.66^{de}	4.00^{cd}	4.00^{cd}
	Bamboo Mat	2.00^{i}	2.00^{i}	3.00^{fg}	3.00^{fg}	2.00^{i}	2.00^{i}	2.33^{hi}	3.00^{fg}	2.00^{i}	2.00^{i}	2.33^{hi}	3.00^{fg}
	Wire Mesh	3.00^{fg}	3.00^{fg}	3.00^{fg}	3.66^{de}	2.33^{hi}	2.66^{gh}	2.66^{gh}	3.00^{fg}	3.00^{fg}	3.00^{fg}	3.00^{fg}	3.00^{fg}
LSD (5%)		0.518											
CV (%)		10.00											

Figures followed by the same letter(s) are not significantly different at P≤0.05

4.8. Correlation Studies

The relationship among drying period, hundred bean weight, percentage bean size and green bean physical as well as cup quality characteristics was assessed and presented in Table 25.The simple correlation analysis showed that drying period has highly significant at (P≤0.01) and positive correlation with hundred bean weight (r=0.21) and significant (P≤0.05) with percentage bean size (r=0.12). It had positive but non-significant correlation with green bean physical characteristics. However, drying period showed significant (P≤0.05) and negative correlation with cup quality attributes (cup acidity (r=0.14), body (r=0.20), flavour (r=0.11), total cup quality (r=0.21)) and negatively but non-significant association with total coffee quality characteristics.

Hundred bean weight was highly significantly (P≤0.01) and positively correlated with percentage bean size (r=0.45), primary defects (r=0.29), total raw quality (r=0.26) and total quality (r=0.28). It also showed significant (P≤0.05) and positive association with secondary defect (r=0.17), odor (r=0.12) and cup quality attributes (acidity (r=0.12), body (r=0.13) and total cup quality (r=0.15)). The result agrees with the findings of Yigzaw (2005) who reported that there is strong correlation between bean weight and percentage bean sizes.

Bean size has highly significant (P≤0.01) and positive association with all physical quality characteristics (primary defects (r=0.23), secondary defects (r=0.34), odor (0.25); total raw quality (r=0.38) and total cup quality (r=0.24) and total coffee quality (r=0.38) attributes. Bean size has also significant (P≤0.05) and positive associations with the cup quality attributes (cleanness (r=0.18), acidity (r=0.19), body (r=0.12), and flavour (r=0.16)). This result was in line with the findings of Yigzaw (2005) who reported that there is strong correlation between bean size and bean weight and good association between bean size and cup body.

Primary defect was highly significantly (P≤0.01) and positively correlated with secondary defect (r=0.23), odor (r=0.29), total cup quality (r= (0.22) and total coffee quality (r=0.54). It is also strongly correlated with total raw quality (r=0.62) .It has also significant (P≤0.05) and positively associated with acidity (r=0.24) and body (r=0.16). Primary defects have negative correlation with grade (r=0.59). Similarly, secondary defects have highly significant (P≤0.01) and positive association with odor (r=0.33), acidity (r=0.34), body (r=0.35), flavour (r=0.33) and total cup quality (r=0.44).It was strongly correlated with total raw quality (r=0.89), and total coffee quality (0.80). Furthermore;there was significant (P≤0.05) and positive association between secondary defects and cup cleanness (0.16). It had weak and highly significant (P<0.01) and negative correlation with coffee grade (r=0.67).

There was highly significant (P≤0.01) and positive association between odor and total raw quality (r=0.53). Odor quality had also strong associations with cup quality characteristics: cleanness (r=0.24) acidity (r=0.35), body (r=0.27), total cup quality (r=0.36) and total quality (0.56). Odor showed non significant relationship with cup flavour. Similarly, the relationship between total raw quality and cup quality attributes was highly significant (P≤0.01) and it has strong positive association with acidity (r=0.41), body (r=0.37), flavour (r=0.28) total cup quality (r=0.46) and total coffee quality (r=0.91) characteristics. Total raw quality was significantly (P≤0.05) and positively correlated with cleanness (r=0.19). This result may suggest the existence of strong linkage between raw quality attributes and both cup and total coffee quality characteristics.

There was highly significant (P≤0.01) and positive association between cup cleanness and acidity (r=0.40), total cup quality (r=0.55) and total quality (r=0.33). Cup cleanness also significant (P≤0.05) and positive association with body (r=0.16), but non significant association with cup flavour.

Acidity as one of the measure of brew or cup quality, had highly significant (P≤0.01) and strongly positive association with body (r=0.36), total cup quality (r=0.75) and total coffee quality (r=0.58). It was significantly (P≤0.05) and positively association with flavour (r=0.16). This result was supported by the findings of Clifford (1985) and EAFCA (2008) indicating that high acidity and good flavour gives better quality and more intense aroma to the beverage. Furthermore, Yigzaw (2005) and Mekonnen (2009) have reported that there was highly significant and strongly positive association between acidity and body, flavour and total coffee quality. Similarly, there was highly significant (P≤0.01) and positive association between body and flavour (r=0.44), total cup quality (r=0.79) and total coffee quality (r=0.56). This result supports the findings of Yigzaw (2005) and Mekonnen (2009) who reported that body has strong and positive association with acidity, flavour and total coffee quality characteristics. The present result agrees with the findings of Yigzaw (2005) who revealed that there was highly significant and strong correlation between flavour and cup acidity and body. Furthermore, there was highly significant (P≤0.01) and positive association between flavour and total cup quality (r=0.57) and total coffee quality (r=0.40).

The total cup quality was highly significantly (P≤0.01) and positively associated with total quality (r=0.71). This result may suggest the existence of strong link between cup quality attribute and total coffee quality. The simple correlation results also showed that total quality was highly significantly (P≤0.01) and negatively associated with coffee grade (r=0.93). Mekonnen (2009) has indicated that total coffee quality is highly significantly and positively correlated with bean weight, cup acidity and body.

Furthermore; coffee grade had highly significant (P≤0.01) and negative correlation with hundred bean weight (r=0.36); percentage bean size (r=0.30); odor. (r=0.59), cup cleanness (r=0.32); acidity (r=0.69); body (r=0.51); flavour (r=0.33) .It has also strong association on total raw quality (r=0.83) and total cup quality (r=0.68). Comparative sensorial tests indicated lower quality values, because the grade classification ECX (2009) outlined in ascending order describing a scale from 1 to 9, where 9 corresponds to the worst cup and 1 to the best.

Table 23. Pearson Correlation Coefficients of coffee quality parameters

	DP	HBW	PBS	PD	SD	OD	TRQ	CL	AC	BO	FL	TCQ	TQ	GR
DP	1	0.21**	0.13*	0.07	0.01	0.03	0.04	-0.07	-0.14*	-0.21*	-0.11*	-0.21*	-0.06	**0.06**
HBW		1	0.45**	0.23**	0.17*	0.12*	0.26**	0.08	0.12*	0.13*	0.08	0.15*	0.28**	-0.30**
PBS			1	0.23**	0.34**	0.25**	0.38**	0.18*	0.19*	0.12*	0.16*	0.24**	0.38**	-0.36**
PD				1	0.23**	0.29**	0.62**	0.08	0.24**	0.16*	0.10	0.22**	0.54**	-0.59**
SD					1	0.33**	0.89**	0.16*	0.34**	0.35**	0.30**	0.44**	0.80**	-0.66**
OD						1	0.53**	0.24**	0.35**	0.27**	0.06	0.36**	0.56**	-0.59**
TRQ							1	0.19*	0.41**	0.37**	0.28**	0.48**	0.91**	-0.83**
CL								1	0.40**	0.16*	0.07	0.55**	0.33**	-0.31**
AC									1	0.36**	0.16*	0.75**	0.58**	-0.62**
BO										1	0.44**	0.79**	0.56**	-0.51**
FL											1	0.57**	0.40**	-0.33**
TCQ												1	0.71**	-0.68**
TQ													1	-0.93**
GR														**1**

** and * = Correlation significant at 1% and 5% level of significance, respectively; ns=non significant; DP=drying period; HBW=hundred bean weight; PBS=percentage bean size; PD=primary defects; SD=secondary defect; OD=odor; TRQ=total raw quality; CL=cleanliness; AC=acidity; BO=body; FL= flavour;TCQ=total cup quality; TQ=total quality and GR=grade

5. SUMMARY AND CONCLUSIONS

Although Ethiopia is known to be the first in Africa in terms of coffee production and eighth major supplier of the global market, its share accounts for only 3% of the global coffee trade. This calls for transition to more dynamic and innovative quality approaches. The study confirmed that there were varietal differences in respect of time of drying. As a result, small sized beans (74110) dried earlier while big sized beans (744) took longer drying period. Varietals differences also vary time of drying period. Hence, drying cherries according to their size is advisable to improve coffee quality. Similarly, time of drying was influenced by the combined effects of location, drying method and cherry layer thickness. As a result at Kossa, drying coffee cherries on raised beds covered with mesh wire with more coffee spread per m^2 took more time to dry while at Gomma-1, successful drying of coffee on bricks floor was achieved earlier than on bamboo mats and mesh wires due to high heat absorption on bricks floor. Therefore; using raised beds took more time of cherry drying, while using bricks floor may save about a week to coffee farmers to accomplish other farming activities.

The total raw quality of coffee was determined by location, drying methods, variety and cherry layer thickness. As a result, at Gomma-2 and Kossa, wherein coffee variety 74110 dried on raised beds covered with bamboo mats and mesh wire using the coffee spread layer thickness of 20kg/m^2 attained the maximum values of mean total raw quality attributes. On the other hand, at Gomma-2, variety 74110 spread and dried on bricks floor at 20 to 40kg/m^2 and treated in the conventional way resulted in the lowest mean total raw quality. As a result, at Gomma-2, Kossa and similar areas, coffee variety 74110 drying on raised beds covered with bamboo mats and mesh wire using the coffee spread layer thickness of 20kg/m^2 improved the total raw quality of green bean.

The synergetic effects of location, sun drying methods and coffee variety dictated the total cup quality. Consequently, at Gomma-1, variety 744, 74110 and 744+74110 dried on raised beds covered with bamboo mats lead to the development of the best mean total cup quality. Moreover; the interaction among locations, drying materials and levels of layer thicknesses was critical in determining the total cup quality. As a result; at Gomma-1, coffee dried on raised beds covered with bamboo mats using layer thickness of 20kg/m^2 revealed the highest mean total cup quality values. At Gomma-2, coffee dried on both raised beds covered with mesh wires and bamboo mats using the same layer thickness of 20kg/m^2 gave rise to statistically identical and the highest mean total cup quality. Furthermore; at Kossa, coffee dried on raised beds covered with bamboo mats and cherry layer thickness of 20 to 30kg/m^2 scored the highest mean total cup quality. On the other hand, at Gomma-1, processing coffee both on bricks floors and raised beds covered with mesh wire using the maximum layer thickness (40kg/m^2) and yet treated in conventional practice attained the lowest mean total cup quality. Moreover; the total cup quality of green coffee was found to be determined by the combined effect of coffee drying methods, variety and levels of layer thickness. Hence, variety 74110 and 744+74110 dried on raised beds covered with bamboo mats and variety 744 and 74110 dried on beds covered with mesh wire using the minimum layer thickness (20kg/m^2) exhibited the highest mean total cup quality. On the other hand, variety 744 dried on bricks floor and raised beds covered with mesh wire and variety 74110 dried on bricks floor using the layer thickness loads of 40kg/m^2 and treated in farmers' conventional practices produced the lowest mean total cup quality. Hence, processing variety 74110 and 744+74110 on raised beds covered with bamboo mats and variety 744 and 74110 on beds covered with mesh wire using the minimum layer thickness (20kg/m^2) improved the total cup quality of sun dried coffee.

The total coffee quality and grade was influenced by the interactions among location, drying method, coffee variety and levels of cherries layer thickness. As a result; at Gomma-1, variety 744 dried on bamboo mats using the layer thickness loads of 20kg/m^2,at Gomma-2, variety, 74110 dried on raised beds covered with mesh wire using cherries loads of 20kg/m^2 and at Kossa; variety 744 and 74110 dried on raised beds covered with bamboo mats with layer thickness of 30 and 20kg/m^2 induced excellent quality coffee detected to "excellent specialties taste" and received a "Specialty Grade 1" (85.00-89.99 points) profiled under grade 2 (under the current commercial grading). As a result; processing coffee at different altitudes after sorting varieties on the basis of their size and spreading on raised beds covered with bamboo mats and mesh wire with appropriate layer thickness could produce a specialty grade coffee .Hence; at Gomma-1, variety 744; at Gomma-2, variety 74110 and at Kossa; variety 744 and 74110 dried on raised beds covered with bamboo mats and mesh wire and layer thickness of 20kg/m^2 induced excellent quality coffee.

At Gomma-1, coffee variety 74110 and 744+74110 dried on raised beds covered with bamboo mats; variety 744 and 74110 dried on raised beds covered with mesh wire by spreading at layer thickness of 20kg/m^2 was produced a better quality coffee and cupped as very good specialty taste (80-84.99 points) profiled under grade 2. On the other hand, variety 744 processed on bricks floor and variety 74110 dried on both bricks floor and raised beds covered with bamboo mats and mesh wire using layer thickness of 40kg/m^2 treated as conventional system was identified to fall according to commercial grades classifications profiled under grade 3 and 4. Hence, at lower altitudes, when small sized beans were dried on bricks floor using thick density levels of cherries induced poor quality coffee. Hence; At Gomma-1 (low land area), coffee variety 74110 and 744+74110 dried on raised beds covered with bamboo mats; variety 744 and 74110 dried on raised beds covered with mesh wire by spreading at layer thickness of 20kg/m^2 produce very good specialty taste profiled under grade 2.

Similarly; at Gomma-2, variety 74110 and 744+74110 dried on raised beds covered with bamboo mats using the layer thickness loads of 20kg/m^2; variety 744 and 744+74110 dried on raised beds covered with mesh wire using the density levels of 20 and 20 to 30kg/m^2, respectively induced better quality detected to be a “very good specialty taste” produce a better quality coffee (80-84.99 points) profiled under grade 2. While, coffee variety 744 and 74110 processed on bricks floor using thick layer loads and treated in the conventional system produced, as commercially graded, a coffee quality profiled under grade 5 and 6. Hence, processing coffee on raised beds covered with bamboo mats and mesh wire using appropriate layer thicknesses (3 to 5cm in deep), which is equivalent to 20 to 30kg/m^2 of fresh cherry produce specialty coffee grades. However, at mid altitudes, when both big and small sized beans were processed on bricks floor by spreading cherries at thick density levels resulted in the production of low quality coffee ranging from grade 5 to 6. Therefore at Gomma-2 (mid land area), variety 74110 and 744+74110 dried on raised beds covered with bamboo mats and mesh wire using the density levels of 20kg/m^2 and 20 to 30kg/m^2; variety 744 dried on raised beds covered with mesh wire using 20kg/m^2 induced better quality.

Furthermore; at Kossa, wherein variety 744 was processed on raised beds covered with bamboo mats at the layer thickness of 20 to 30kg/m^2;variety 74110 dried on raised beds covered with bamboo mats and mesh wire with cherry layer thickness of 20 to 40kg/m^2 and 20 to 30kg/m^2, and variety 7411+74110 dried on raised beds covered with bamboo mats using the layer thickness of 20 to 40kg/m^2, respectively attained a better quality coffee which is considered to be very good specialty taste profiled under grade 2. Hence; properly processed coffee on both raised beds covered with bamboo mats and mesh wire using cherry layer thickness of 20 to 40kg/m^2 produce a better quality coffee (80-84.99 points) profiled under grade 2. While, the farmers' conventional system wherein coffee cherries are continuously added to a layer thickness of 40kg/m^2 produced coffee quality ranging from grade 3 to 4. Hence; at higher altitudes, Processing coffee on drying tables covered with bamboo mats and mesh wire imparted better quality grades whereas; the farmers' conventional systems produced low quality coffee. Therefore, special attention should be given to dry processing approaches through refinement of sun drying methods for quality improvement of dry processed Arabica coffee. Consequently, based on the interest of consumers and specialty market, producing high quality coffee earns more income for coffee farmers in particular and the coffee industry as a whole.

6. RECOMMENDATIONS

With this research out puts, coffee growers are able to modify their locally affordable sun drying methods to raise the quality of coffee. It is crucial that considerable modifications to all stages of traditional coffee processing system that has been practiced in Jimma area. Processing coffee using appropriate levels of layer thickness on raised beds covered with bamboo mats and mesh wire is needed to improve the quality of dry processed Arabica coffee. Results of the present study show that the traditional coffee dry processing approaches may result in inferior quality of beans, and, thus should be modified in such away that would improve coffee qualities. In order to be competent in the global market, the country should produce high quality coffees, which can fetch premium prices for the benefit of the growers and the country as a whole. On the basis of its affordability appropriate dry processing with sun-drying methods uses fewer infrastructures to produce high quality coffee. Hence, primary processing practices in replicated areas would help to come up with more conclusive recommendations. Therefore; it is advisable to use the following processing approaches:

- Varietals differences can alter time of drying period. Hence, drying cherries according to their size and variety is advisable to improve coffee quality
- At Gomma-2, Kossa and similar areas, coffee variety 74110 drying on raised beds covered with bamboo mats and mesh wire using the coffee spread layer thickness of 20kg/m^2 attained improved total raw quality
- At Gomma-1 (low land area), coffee variety 74110 and 744+74110 dried on raised beds covered with bamboo mats; variety 744 and 74110 dried on raised beds covered with mesh wire by spreading at layer thickness of 20kg/m^2 produce very good specialty taste profiled under grade 2
- At Gomma-2 (mid land area), variety 74110 and 744+74110 dried on raised beds covered with bamboo mats and mesh wire using the density levels of 20kg/m^2 and 20 to 30kg/m^2; variety 744 dried on raised beds covered with mesh wire using 20kg/m^2 induced better quality
- At Kossa (high land area),wherein variety 744 was processed on raised beds covered with bamboo mats at the layer thickness of 20 to 30kg/m^2;variety 74110 dried on raised beds covered with bamboo mats and mesh wire with cherry layer

thickness of 20 to 40kg/m^2 and 20 to 30kg/m^2, and variety 7411+74110 dried on raised beds covered with bamboo mats using the layer thickness of 20 to 40kg/m^2, respectively attained a better quality

- ❖ Further study should be done to give more concrete recommendations for coffee varieties at different locations with different drying methods and appropriate levels of layer thickness
- ❖ Since the conventional practices that the farmers are using has to be discouraged; It is crucial that to all stages of traditional coffee processing system that has been practiced in Jimma area needs considerable modifications

Future Line of Work

Coffee quality can be best improved through application of appropriate dry processing practices. Hence, from the present findings, gaps have been identified for future research consideration:

- ➢ Optimization of sun drying methods/materials on the basis of agro-ecologies and farmers indigenous practices
- ➢ Determination of stirring frequencies on cherry drying at different locations.
- ➢ Promoting action research and increasing awareness through training and demonstration of improved dry processing methods need due attention.

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APENDICES

Appendix Table I. Combined analysis of variance of P-values for dry processed raw coffee quality characteristics

Source of variation	**DF**	**Raw Coffee Quality Characteristics**						
		DP	**HBW**	**PBS**	**PD**	**SD**	**OD**	**TRQ**
Replication	2	0.0372	0.1866	0.0727	0.5960	0.9399	0.6216	0.9970
Location	2	<.0001	<.0001	<.0001	<.0001	<.0001	0.0109	<.0001
E-Loc.	4	0.1048	0.0228	0.4131	0.2133	0.9581	0.1117	0.8715
Drying	2	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
L X D	4	<.0001	<.0001	<.0001	<.0001	<.0001	0.0049	<.0001
E-L X D	12	0.8654	0.0140	0.3751	0.3209	0.4341	0.3374	0.5942
Variety	2	0.0025	<.0001	0.2340	<.0001	0.0018	0.5688	0.0518
L X V	4	0.1309	<.0001	0.1457	<.0001	<.0001	0.0240	<.0001
D X V	4	0.9620	0.0249	0.1707	<.0001	0.5716	0.0172	0.1179
L X D X V	8	0.9705	0.0590	0.1392	<.0001	0.0213	0.5106	0.0011
E-L X D X V	36	1.0000	<.0001	0.8225	0.0005	0.8703	0.0160	0.9812
Layer Thickness	3	<.0001	0.4214	0.1542	<.0001	<.0001	<.0001	<.0001
L X LT	6	0.0266	0.5927	0.1027	<.0001	<.0001	0.0018	<.0001
D X LT	6	0.2187	0.8905	0.2053	<.0001	<.0001	<.0001	0.0004
V X LT	6	0.8415	0.0524	0.5934	0.0121	0.0109	0.8987	0.1766
L X D X LT	12	0.0072	0.5641	0.0408	<.0001	<.0001	0.3374	0.0079
L X V X LT	12	0.9673	0.2400	0.3404	0.0117	0.6913	0.0491	0.8505
D X V X LT	12	0.8970	0.0202	0.4924	0.0015	0.1635	0.0064	0.0204
L X D X V X LT	24	0.9997	0.0581	0.5430	0.0016	0.0027	0.2431	0.0047
E-LX DXVXLT	162	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
CV (%)		5.62	3.37	1.31	4.82	14.40	5.80	8.22

R=replication;L=location;E-Loc=error for location(factorA);D= Drying; LXD=interaction between location and drying material ;E-LXD=error of drying materials(factor B);V = *Variety; LXV=interaction between locations and variety;DXV=interaction between drying materials and locations;LXDXV=three way interactions* E-LXDXV=error for variety(factor C); *LT=Layer thickness; LXLT;DXLT;VXLT=two way interactions; LXDXLT; LXVXLT; DXVXLT=three way interactions;LXDXVXLT=four way interactions;;E-LXDXVXLT=error for layer thickness(factor D); CV=Coefficient of variance. ;DF=Degrees of freedom ;DP=Drying period;HBW=hundred bean weight;PBS=percentage bean size;PD=primary defects;SD=secondary defects;OD=odor and TRQ=total raw quality.*

Appendix Table II. Combined analysis of variance of P-values for dry processed organolephtic coffee quality characteristics

Source of variation	DF	Organolephtic Coffee Quality Characteristics						
		CL	**AC**	**BO**	**FL**	**TCQ**	**TQ**	**GR**
Replication	2	0.5344	0.5321	0.0501	0.5838	0.7402	0.7287	0.9705
Location	2	0.0416	0.0133	0.0014	0.0996	0.0001	<.0001	<.0001
E-Loc.	4	0.5919	0.9193	0.3140	0.7723	0.4775	0.7240	0.7504
Drying	2	0.0239	<.0001	<.0001	0.0003	<.0001	<.0001	<.0001
L X D	4	0.0012	0.5779	0.1832	0.0103	0.2046	<.0001	<.0001
E-L X D	12	0.0724	0.2431	0.6174	0.3554	0.1382	0.7970	0.5787
Variety	2	0.2609	0.5877	0.2935	0.2864	0.3352	0.0067	0.2330
L X V	4	0.1654	0.0263	0.0198	0.2231	0.0011	<.0001	<.0001
D X V	4	0.8994	0.8203	0.1167	0.5794	0.6813	0.0850	0.0041
L X D X V	8	0.1886	0.3602	0.4037	0.0723	0.0402	<.0001	<.0001
E-L X D X V	36	0.0472	0.9554	0.7551	0.7681	0.6872	0.3300	0.6107
Layer Thickness	3	0.0018	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
L X LT	6	0.0002	0.0037	0.1637	0.0001	0.0057	<.0001	<.0001
D X LT	6	0.0391	<.0001	0.0005	0.0003	0.0366	0.0636	0.0485
V X LT	6	0.9783	0.8782	0.8815	0.8371	0.9283	0.5321	0.7695
L X D X LT	12	0.0578	0.0021	0.5619	0.0171	0.0004	<.0001	<.0001
L X V X LT	12	0.6763	0.2644	0.5366	0.0061	0.3867	0.1773	0.1252
D X V X LT	12	0.5053	0.2135	0.0451	0.1364	0.0281	<.0001	0.0023
L X D X V X LT	24	0.7351	0.0119	0.1065	0.2817	0.1262	<.0001	0.0337
E-LX DXVXLT	162	0.0021	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
CV (%)		5.12	8.04	10.53	7.35	4.38	3.10	10.00

R=replication;L=location;E-Loc=error for location(factorA);D= Drying;; LXD=interaction between location and drying material ;E-LXD=error of drying materials(factor B);V = *Variety; LXV=interaction between locations and variety;DXV=interaction between drying materials and locations;LXDXV=three way interactions* E-LXDXV=error for variety(factor C); *LT=Layer thickness; LXLT;DXLT;VXLT=two way interactions; LXDXLT; LXVXLT; DXVXLT=three way interactions;LXDXVXLT=four way interactions;;E-LXDXVXLT=error for layer thickness(factor D); CV=Coefficient of variance. ; DF=Degrees of freedom; CL=cleanliness'=acidity; BO=body;FL=flavor and TCQ=total cup quality.*

Appendix Table III.Experimental Layout of Field Processing at Gomma -1

Bricks Floor

$L_1D_1V_1+V_2T_3$	**$L_1D_1V_1+V_2$conv**	**$L_1D_1V_1+V_2T_1$**	**$L_1D_1V_1+V_2T_2$**	**$L_1D_1V_2T_1$**	**$L_1D_1V_2T_2$**	**$L_1D_1V_2$ conv**	**$L_1D_1V_2T_3$**	**$L_1D_1V_1T_1$**	**$L_1D_1V_1T_3$**	**$L_1D_1V_1T_2$**	**$L_1D_1V_1$conv**

$L_1D_1V_2$conv	**$L_1D_1V_2T_2$**	**$L_1D_1V_2T_3$**	**$L_1D_1V_2T_1$**	**$L_1D_1V_1T_2$**	**$L_1D_1V_1T_3$**	**$L_1D_1V_1$conv**	**$L_1D_1V_1T_1$**	**$L_1D_1V_1+V_2T_3$**	**$L_1D_1V_1+V_2$ conv**	**$L_1D_1V_1+V_2T_1$**	**L**

$L_1D_1V_1T_1$	**$L_1D_1V_1T_3$**	**$L_1D_1V_1T_2$**	**$L_1D_1V_1$ conv**	**$L_1D_1V_2$conv**	**$L_1D_1V_2T_1$**	**$L_1D_1V_2T_3$**	**$L_1D_1V_2T_2$**	**$L_1D_1V_1+V_2T_1$**	**$L_1D_1V_1+V_2$conv**	**$L_1D_1V_1+V_2T_2$**	**$L_1D_1V_1+V_2T_3$**

Bamboo Mats

$L_1D_2V_1+V_2T_3$	**$L_2D_2V_1+V_2$conv**	**$L_1D_2V_1+V_2T_1$**	**$L_1D_2V_1+V_2T_2$**	**$L_1D_2V_2T_3$**	**$L_1D_2V_2T_1$**	**$L_1D_2V_2T_2$**	**$L_1D_2V_2$ conv**	**$L_1D_2V_1T_2$**	**$L_1D_2V_1$conv**	**$L_1D_2V_1T_1$**	**$L_1D_2V_1T_3$**

$L_1D_2V_1T_3$	**$L_1D_2V_1T_1$**	**$L_1D_2V_1T_2$**	**$L_1D_2V_1$ conv**	**$L_1D_2V_1+V_2T_2$**	**$L_1D_2V_1+V_2$conv**	**$L_1D_2V_1+V_2T_1$**	**$L_1D_2V_1+V_2T_3$**	**$L_1D_2V_2T_3$**	**$L_1D_2V_2T_1$**	**$L_1D_2V_2$ con**	**$L_1D_2V_2T_2$**

$L_1D_2V_{1+}V_2$ con	**$L_1D_2V_{1+}V_2$ T_3**	**$L_1D_2V_{1+}V_2$ T_2**	**$L_1D_2V_{1+}V_2$ T_1**	**$L_1D_2V_2$ T_2**	**$L_1D_2V_2$conv**	**$L_1D_2V_2T_1$**	**$L_1D_2V_2$ T_3**	**$L_1D_2V_1$ T_1**	**$L_1D_2V_1$ T_2**	**$L_1D_2V_1$ T_3**	**$L_1D_2V_1$conv**

Mesh wire

$L_1D_3V_1T_3$	**$L_1D_3V_1$ conv**	**$L_1D_3V_1T_2$**	**$L_1D_3V_1T_1$**	**$L_1D_3V_1+V_2T_2$**	**$L_1D_3V_1+V_2T_1$**	**$L_1D_3V_1+V_2$conv**	**$L_1D_3V_1+V_2T_3$**	**$L_1D_3V_2$ conv**	**$L_1D_3V_2T_2$**	**$L_1D_3V_2T_3$**	**$L_1D_3V_2T_1$**

$L_1D_3V_2$conv	**$L_1D_3V_2T_1$**	**$L_1D_3V_2T_3$**	**$L_1D_3V_2T_2$**	**$L_1D_3V_1+V_2T_2$**	**$L_1D_3V_1+V_2$conv**	**$L_1D_3V_1+V_2T_1$**	**$L_1D_3V_1+V_2T_3$**	**$L_1D_3V_1T_1$**	**$L_1D_3V_1$ conv**	**$L_1D_3V_1T_3$**	**$L_1D_3V_1T_2$**

$L_1D_3V_1T_1$	**$L_1D_3V_1T_2$**	**$L_1D_3V_1T_3$**	**$L_1D_3V_1$ conv**	**$L_1D_3V_2T_2$**	**$L_1D_3V_2$conv**	**$L_1D_3V_2T_1$**	**$L_1D_3V_2T_3$**	**$L_1D_3V_1+V_2T_1$**	**$L_1D_3V_1+V_2T_3$**	**$L_1D_3V_1+V_2$conv**	**$L_1D_3V_1+V_2T_2$**

Remark: **L_1=**Location one=Gomma-1 ; **L2 = Location two =Gomma two and L3= Location three=Koss**a

- **D_1**=Drying Material one=Bricks Floor ; **D_2 =** Drying Material two=Bamboo mats **and D_2= Drying Material three=mesh wire**
- **V_1**=Variety one=741 ; **V_2=Variety two=74110 and V_3=Variety three= 741 +74110**

Appendix Table IV. Metrological data of the experimental stations at the study period in 2010

Date	Rainfall Distribution(mm)								
		October			**November**			**December**	
	Gomma-1	**Gomaa-2**	**Kossa**	**Gomma-1**	**Gomaa-2**	**Kossa**	**Gomma-1**	**Gomaa-2**	**Kossa**
1									
2		10.5	8.2						
3		9.5	22.1						
4		10.5	4.8						
5			0.9						
6			3.2						
7									
8									
9			6.9						2.2
10									2.5
11									
12						5.5		10.5	
13					10.5			8.5	
14		2.5							
15									
16	**No data**		60.9	**No data**			**No data**		
17		2.5							
18									
19									
20									
21						11.0			
22		8.5			5.5	42.3			
23					36.0	5.1			
24									
25									
26		1.5			8.5	1.4			
27									
28		25.0							
29									12.5
30									
31									3.7
Average		8.8	15.3		15.1	16.3		9.5	5.2

Source: LCPE (Annual report, 2010/11; Unpublished data)

Appendix Table V. Green bean size determination of Arabica coffee variety at the study areas

Variety	**Location**	**Average bean weight(g) retained above screen size number**							
		>20	**19**	**18**	**17**	**16**	**15**	**14**	**<14(pea berry)**
744	Gomma-1	6.00	11.90	53.33	97.33	102.2	52.43	21.2	5.6
	Gomma-2	3.00	8.06	34.03	86.47	103.27	69.67	36.7	8.8
	Kossa	7.00	13.47	31.33	76.86	109.1	78.2	28.97	5.06
74110	Gomma-1	2.87	6.00	34.07	107.87	121.57	57.06	17.03	3.53
	Gomma-2	2.00	5.23	22.45	55.14	106.97	105.98	43.84	8.4
	Kossa	2.87	2.00	11.33	48.87	127.9	112.6	39.07	5.53
744 +74110	Gomma-1	3.07	10.00	33.37	119.06	83.03	52.7	45.00	3.77
	Gomma-2	2.10	9.00	22.00	61.96	105.73	94.17	48.17	6.87
	Kossa	3.00	8.33	21.47	74.1	120.97	80.96	36.50	4.67

Appendix Table VI. Standard parameters and their respective values used for unwashed coffee quality evaluation and grading as per ECX (2009)

Unwashed Coffee Quality Assessment

Raw value _____ Moisture content________%

Cup value_______ Retained on screen_______%

Total point_______

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	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

Source :(ECX, 2009)

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; grade9=20-30; under grade=15-19; CD= Cup defect; ND= Not detected

Name Signature

Classification:______ Coordinator **(Cupper 1)** Name:______________________ =========

Cupper 2:____ ========

Grade:____________ Cupper 3: _______________________________________ ========

Appendix Table VII. Raw defect type & evaluation system of SCAA and Ethiopia unwashed green coffee bean

Raw defects											
SCAA primary defects		Secondary defects observations									
Type	Bean grade	SCAA	0	1	2	3	Ethiopia	0	1	2	3
Full black		Partial black					Foxy				
Full sour		Partial sour					Under dried				
Fungus		Floater					Over dried				
Foreign matter		Immature					Mixed				
Insect damaged		Withered					Stinkers				
Pod/Husk		Shell					Faded				
		S.insect damaged					Coated				
		Broken					Light				
		Soiled					Starved				
Total (Transfer to grade table)		Total									

Source: ECX (2009)

APPENDIX FIGURE

Appendix Figure A. Primary processing of Arabica coffee at the experimental Stations

Red ripe cherries ready for Harvesting

loading of bamboo mats and pieces of frames

Bricks floor ready for drying

Raise beds with mesh wire

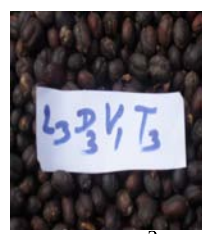
Drying on bricks floor

Drying on bamboo mats

Field visit of coffee

($20kg/m^2$)

($30kg/m^2$)



($40kg/m^2$)

Appendix Figure B. Secondary processing (Hulling) and packaging operations

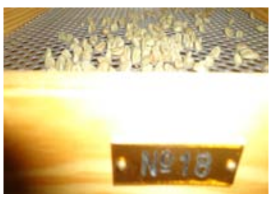
Hulling (de-husking) Operations **Soarting of coffee** **Packaging of coffee**

Appendix Figure C. Raw Quality analysis of Unwashed Arabica coffee

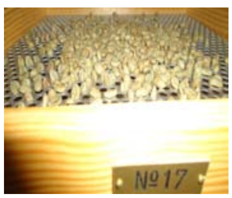
Moisture taster

Different sized sieves

Determination of bean size



Screen No.18



Screen No.17

Screen No.16

Screen No.15

Appendix Figure D. Organolephtic Quality analysis of Unwashed Arabica coffee


Coffee Roasting


Coffee Roasting


Measuring roasted Coffee


Roasted coffee


Brewing Coffee


Brewed coffee ready for testing


Cup testing


Cup testing