Effect of Natural and Artificial Drying Method on the Quality of Wet Processed Arabica Coffee *(Coffea arabica L.)*

M.Sc. THESIS

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APRIL, 2013

JIMMA ETHIOPIA

Effect of Natural and Artificial Drying Method on the Quality of Wet Processed Arabica Coffee *(Coffea arabica L.)*

M.Sc. Thesis

By

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Submitted to the School of Graduate Studies

Jimma University, College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of Master of Science in post harvest management (Specialization: perishable)

APRIL, 2013

JIMMA ETHIOPIA

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by Atikilti Tilahun entitled '**Effect of Natural and Artificial drying method on the quality of wet processed arabica coffee *(C. arabica)* varieties.'** I recommend that it be submitted as fulfilling thesis requirement.

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As members of the *Board of Examiners of the M.Sc. Thesis Open Defense Examination,* we certify that we have read and evaluated the thesis prepared by Atikilti Tilahun and examined the candidate .We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in post harvest management (perishable)

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DEDICATION

I dedicate this thesis to my beloved family for all the sacrifices, wishes and praiseworthy to success in all my endeavors.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is the result of my own work and that all sources or 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 confidently declare that this thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

Atikilti Tilahun Ayalew was born in **H**arer region on February, in 1986. She attended Elementary, Junior Secondary and High School education at Jemary Elementary School, Negadesefer Junior Secondary and Batu Terara High School, respectively. She joined Jimma University, College of Agriculture and Veterinary Medicine in 2004 and graduated on 2007 with B.Sc degree in crop production and protection. After graduation she was employed in wush-wush Tea Development to serve as researcher and unit farm manager for one year and four month. After this much time she got to Elfora agro industry as table grape project supervisor for one year and six month. Then after, she joined Jimma University College of Agriculture and Veterinary Medicine in September 2010 to pursue graduate studies for the M.sc. post harvest management.

ACKNOWLEDGEMENTS

Above all, I am very grateful to God Almighty who is always with me in all my steps and helped me to complete this thesis work. I am also very grateful to my major advisor Dr. Ali Mohammed for his follow up, meticulous guidance, encouragement, and assistance in, review and comments on the manuscript. I would like to extend my special thanks to my co-advisor Ato Behailu W/Senbet, who always in touch with me, follow up my work, and helped me in shaping up the manuscript.

I extend my sincere thanks to Dr. Girma Adugna, Mr. Amsalu Nabyu ,Mr. Solomone Edris, Mr. Yehenew Getachew who helped me shaping up my first draft proposal, in analyzing my data and sharing ideas by spending their precious time and invaluable input while writing the thesis manuscript.

I am grateful to Oxfam Great Britain for providing the financial support for the research. And also I am thanking full CIDA project to sponsoring the studding program and paying the salary.

I would like to extend my sincere thanks to Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) staffs for their help in facilitating all the necessary supports to accomplish my research work.. This thesis would have not been complete without their assistance. I am also highly indebted to Limmu Coffee Plantation Development Enterprise (LCPDE) and its sub-farms: Limu Kossa for their support in execution of on-farm coffee processing. Similarly, I am thankful to the ECX (Ethiopian commodity exchange) for allowing me to use their coffee laboratory for quality analysis. I am also highly indebted to expert cuppers: Mubarak, Getenet and who were highly appreciated for their commitment in doing coffee quality analysis.

I am extremely lucky to have favorites and friends: Mr.Mulu ,Miss.Rahel, Mr.Ammanuel, Endalkachew Negusse, Mr.Berhanu Tegaye, Mr. Berehanu Megersa, Mr. Chemeda,Mr.Weyessa Garedew Mr. Essubalew Getachew, Negatu Tuge, Miss. Lelese

Tilahun, Mr.Aberar Shuhla,Terhas Mebratu, who have special place in my heart for their good will and assistance contributed to my study.

I would like to thank all my families, especially my Father, Mother, Sisters and Brothers. Their love, encouragement, moral support and patience have made this work possible. I also acknowledge individuals who helped me in one or another way during my study.

ABBREVIATIONS

ANOVA	Analysis of Variance
CLU	Coffee Liquoring Unit
CQIP	Coffee Quality Improvement Program
CQP	Coffee Quality Program
CRD	Completely Randomized Design
DMRT	Duncan's Multiple Range Test
EAFCA	East African Fine Coffee Association
ECX	Ethiopian Commodity Exchange
EIAR	Ethiopian Institute of Agricultural Research
ESBN	Ethiopian standard bulletin number
FAO	Food and Agriculture Organization
FAQ	Fair Acceptable Quality
HTST	High temperature short time
IAR	Institute of Agricultural Research
ICO	International Coffee Organization
IPO	Intellectual Property Office
ISO	International Standard Organization
ITC	International Trade Center
JARC	Jimma Agricultural Research Center
JZARDO	Jimma Zone Agricultural and Rural Development Office
LCP	Limu coffee plantation
MoARD	Ministry of Agriculture and Rural Development
M.C.	Moisture Content
OTA	Ochratoxin A
'Q'	Quality
QIU	Quality Impact Units
SAS	Statically Analysis Software
SCAA	Specialty Coffee Association of America
UG	Under Grade

UGQ	Usual Good Quality
US	United States

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The effect of Natural and Artificial drying method on the quality of wet processed Arabica coffee *(Coffea Arabica)*

ABSTRACT

*Coffee is the most important crop in the national economy of Ethiopia and still the leading export commodity. The country's export earnings from this crop exceed all other agricultural products. Though Jimma is well known as the center of coffee diversity and high production potential area in Ethiopia, owing to the improper post-harvest processing technique, of which on-farm processing is the major one, 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 effect of Natural and Artificial drying method on the quality of wet processed Arabica coffee varieties (Coffea arabica***)** *Accordingly, a study was conducted under state owned coffee farms of Limmu Coffee Plantation (LCP) from October to December, 2012. The experiment was laid out in 4x5 factorial design arranged in CRD with three replications. The two factors comprised five level of temperature:* 60^0C, 70^0C, 80^0C, 90^0C *and sun drying, assigned to the first factor; four initial moisture content: 16%,21%,26% and 40% the second factor Cupping was done by three cuppers at Ethiopian commodity exchange (*ECX) *coffee cupping laboratory in March, 2012.The data were checked for normality and analyzed using SAS version 9.2 and means were separated using least significant differences (LSD). As a result, the interaction effects were highly significant (*$P \leq 0.05$*) for drying period and significant variations were observed (*$P \leq 0.05$*) for acidity, flavor, total cup quality, total quality and coffee grades. The findings revealed that, depending on different working experience of the state farms and the range of drum temperature. Drying wet processed coffee with an initial moisture content of 16% using an artificial drier whose drum temperature is fixed at* 90^0C *resulted in total quality values ranging from 91 to 100% (91.66%) attaining a "specialty grade 1 "classification". While, Coffee with an initial moisture content 40% and dried in an artificial drier with drum temperature ranging from 60 to* 90^0C *resulted in lower quality, the quality standards of coffee and produced low quality commercial grade classified under 3. Hence, using appropriate drying method, it is possible to produce specialty coffee. From the correlation result coffee grade had highly significant (*$P \leq 0.05$*) and negative correlation with acidity (r=-0.69); flavor (r=-0.60); cup value (r=-0.80) and total value (r=0.89); The results of the present study would uplift the quality of wet processed coffee in the area of coffee production, which in turn could enhance the income of individual coffee growers, private investors, exporters in particular and the country at large. However, further study including Identification of the processing techniques and actual differences in quality on distinctively processed coffee, Designing and developing household level electrical assisted or solar assisted artificial dryer to maintain the quality of coffee and identifying the effect of artificial and sun drying on the fungal development in coffee during short time storage and action research to improve the processing practices should be conducted to come up with concrete recommendations.*

1. INTRODUCTION

The genus *Coffea* consist more than one hundred different species. The species vary in terms of chemical composition (Clifford, 1985). Coffee beans are produced from the berries of a small, tropical evergreen tree, and are the source of one of the world's most popular beverages. There are two common species of coffee, that is arabica (*Coffea arabica)* and cofee robusta *(Coffea canephora)*. And within *C. arabica* the variability in quality takes a particular pattern with mutants presenting specific quality attributes such as caturra (dwarf, high productivity sometimes linked to a drop in quality) or maragogype (very large beans low productivity but highly priced). In addition, some mutants have been identified, especially regarding low caffeine contents, such as *C. Arabica* L. variety Laurina (0.6 % dm) and more recently, in Ethiopia origin with traces of caffeine.

Coffee (*Coffea arabica L.*) is the most important agricultural commodity and beverage enjoyed throughout the world and worth up to US $ 14 billion annually for producing country, and more than 80 countries, including Ethiopia, cultivate coffee, which is exported as raw, roasted or soluble product to more than 165 countries worldwide providing a livelihood for an estimate of some 100 million people around the world (ICO, 2001). Many countries are involved in coffee production, trade, communication and it is estimated that, more than 125 countries export and re-export coffee products. In addition, more than 50 developing countries are earning 25 % of their foreign exchange from coffee (CTA, 1999; ITC, 2002).

The importance of coffee in the world economy is clear because it is one of the most valuable primary products in world trade. Its cultivation, processing, trading, transportation and marketing provide employment for millions of people worldwide. In Ethiopia, about 25 % of the total populations of the country are dependent on production, processing, distribution and export of coffee. It accounts for more than 25 % of the GNP, 40 % of the total export earnings, absorbing 25 % of the employment opportunity for both rural and urban dwellers, and 10% of the total government revenue GDP (CTA, 1999; MoARD, 2008).

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

Ethiopia is believed to be the primary centre of origin and genetic diversity for Arabica coffee (*Coffea arabica L.*). Ethiopia is well known not only for being the home of Arabica coffee but also for its very fine quality coffee with the unique aroma and flvor. Among coffee type distinguish for such characteristics are Limu coffee. In Ethiopia, coffee can grow in a wide range of agroecology from 550 m above sea level (m.a.s.l) to 2000 m.a.s.l (Paulos and Teketay, 2000). The diversity of coffee, soil and climate, together with production and processing methods, among others, enable the country to produce and supply the de facto organic coffees (Taye and Tesfaye, 2002). Ethiopian coffee is processed in two processing techniques, namely, natural sun-dried (70%) and washed (30%) coffees.

Ethiopia, Africa's largest Arabica coffee producer and the original home of *Coffea arabica* L, and possesses the largest diversity in coffee genetic resources (Girma, 2003). (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 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). The annual coffee production is normally in the range of 300,000-330,000 tones, which is about 600 kg/ha. Although Ethiopia is Africa's 1st and world's 5th largest Arabica coffee producer (Alemayehu *et al*., 2008).
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; cited by (Tadesse and Feyera 2008), annual production of Ethiopia is on an increasing trend from 3,693,000 bags in 2002 to 5,733,000 bags in 2007.

Jimma Zone is one of coffee growing zones in Oromia Regional State, which has a total area of 1,093,268 hectares of land (JZARDO, 2008). Currently, the total area of land covered by coffee in the zone is about 105,140 hectares, which includes small-scale farmers' holdings as well as state and private owned plantations. Out of the 40–55 thousand tons of coffee annually produced in the Zone (JZARDO, 2008), about 28-35 thousand tons is sent to the central market, while the remaining is locally consumed (Alemayehu *et al*., 2008). Nowadays, Jimma Zone covers a total of 21% of the export share of the country and 43% of the export share of the Oromia Region (JZARDO, 2008). Coffee is the major cash crop of the Zone, which is produced in the eight woredas namely, Gomma, Manna, Gera, Limmu Kossa, Limmu Seka, Seka Chokorsa, Kersa and Dedo, which serves as a major means of cash income for the livelihood of coffee farming families According to the report from the same source, 30-45 % of the people in Jimma Zone are directly or indirectly benefited from the coffee industry.

Despite the favorable climatic conditions, variety of local coffee types for quality improvement and long history of its production in Jimma Zone, coffee quality is declining from time to time due to several improper pre-and post-harvest management practices. This is still practiced by the majority of coffee farmers/traders, from which the larger portion of the produce is obtained. These quality problems are mainly associated with poor agronomic practices like uncontrolled shade level, lack of stumping, pruning and weeding; poor harvesting practices, such as stripping and collecting dropped fruits from the ground; improper post harvest processing and handling practices such as drying on bare ground, improper storage and transportation (Desse, 2008). In addition to this, natural impediment such as prolonged rainy weather, particularly during harvesting and drying season can also contribute to reduced coffee quality. For instance, (Desse, 2008) reported that out of Jimma coffee sent to the coffee quality inspection center laboratory from 2003 to 2007, more than 60% of dry processed coffee classified into grade 3 as compared to 80% of wet processed into grade 2 and grade 3. The author indicated the problem of post harvest processing and handling in the area resulted in poor quality as the main contributing factor. The poor quality and the subsequent drop in earnings had severely affected coffee farmers in woredas like Gomma, Limmu Kossa, and Manna, where coffee provides a larger portion of their annual income. On the contrary, Jimma Zone is known for some quality coffee types such as Limmu Enaria (Limmu) coffee, which is known for its best quality in the world market.

Despite the critical importance and value given to the quality there was no extensive coffee quality research conducted in the country except on fermentation, drying depth and time of storage (Solomon and Behailu,2006). However, there was a piece of work done by Getu (2009) and Yigzaw (2005) on organoleptic quality traits variation with respect to genotype by environment interaction.

Furthermore, Brownbridge and Eyassu (1968) characterized coffees from Limmu Kossa, Gera and Agaro areas based on the bean shape and other quality assessments using raw, roasted and liquor characteristics.

Despite the favorable climatic conditions, variety of local coffee types for quality improvement and long history of its productions, still there are gaps such as lack of profound assessment works to identify the specific coffee quality problems such as drying method and lack of adequate information on the effects of post harvest processing and handling techniques on coffee quality. Hence, this study was designed to address the above mentioned problems thereby forward ways and means that will help growers and processors to produce better quality coffee.

It is repeatedly stated that coffee is the most important export commodity crop for Ethiopia. Ethiopia's different agro ecological zones with different elevations and climates provide great potential for the development of coffee plantation.

Statement of the problem

Among the introduced technologies, coffee drying machines is the one to alleviate or solve problem of decline the quality due to wrong drying and to reduce the burden of female during searing, especially in rainy season. But the effect of natural and artificial drying method on the quality of wet processed Arabica coffee varieties *(C. Arabica L.)* are not studied and well under stood and due to lack of knowledge about the appropriate method of drying techniques, there is a significant loss of quality. On the other hand there is a research gap on the effect of natural and artificial drying method on the quality of wet processed Arabica coffee so as to reduce loses. Thus, a detail investigation to identify technical recommendations for wet processing practices is required. Therefore, this experiment will be carried out to identify suitable drying method to get better quality of coffee and to minimize the quality loss due to improper drying and to minimize the burden of the female during stirring and covering of the bean on the night time and rainy time. Currently, majority of Ethiopian washed coffee is sun dried, which requires more number of days, labor, drying space and limited by weather condition.

Hence, artificial driers are recently introduced, in which quality coffee is seriously affected by Type of coffee, initial moisture of parchment coffee, temperature of drier and duration of drying.

To date, there is limited research effort to compare and optimize natural and artificial drying method on the quality of wet processed Arabica coffee *(C. arebica L.)*
This calls for an on-site and comprehensive study that targets the optimization of unit operations for artificial drying of washed parchment coffee. The effect of natural and artificial drying method on the quality of wet processed arebica coffee is essential in taking measures to minimize or at least to alleviate the loss of quality during drying. Researchers and extension specialists can utilize the results of this study in fine-tuning research and extension activities. Hence, the effect of natural and artificial drying method on the quality of wet processed arebica coffee varieties and its rate and intensity of adoption by smallholder farmers' in the study area. Also farmers, especially the females, development policy makers can benefit from the result of this study since they require micro level information to formulate suitable policies.

Hence; this study is initiated and designed to examine the effect of natural and artificial drying method on the quality of wet processed Arabica coffee *(C. arabica* L.*)* on the basis of the following objectives:

General Objective:

- To evaluate the effect of natural and artificial drying methods on the quality of wet processed Arabica coffee

Specific objectives

- To determine the optimum initial parchment moisture content and identify appropriate drying method and drying temperature for better quality coffee

- To identify appropriate drying method to get better quality and to maintain the intrinsic quality of coffee

2. LITERATURE REVIEW

Coffee (*Coffea arabica* L.) is the most important plantation crop and one of the most common beverages enjoyed throughout the world. It generates up to US$ 14 billion annually for the producing countries. More than 80 countries, including Ethiopia cultivate coffee, which is exported as raw, roasted, or soluble product to more than 165 countries worldwide providing a livelihood for some 100 million people around the world (ICO, 2001).

Ethiopia is considered as the primary center of origin and diversification for arabica coffee (*Coffea arabica* L) and high genetic variability is expected to exist for yield and components of yield, diseases and pest resistance and other traits (Meyer, 1965; Sylvain, 1958;; Mesfin Ameha, 1980). However, despite the vast area of cultivation, wealth of tremendous genetic diversity and importance to the national economy, the productivity of coffee per unit area remained very low with the average national yield hardly exceeding 0.5 t/ha clean coffee. The major contributing factors for such low yield include the limited availability and adoption of improved coffee cultivars and lack of well characterized and distinctly variable breeding materials that are readily available for use.

2. 1.Factor affecting the quality of coffee

Cup quality is a complex characteristic which depends on a series of factors such as the species or variety (genetic factors), environmental conditions (ecological factors), agronomical practices (cultivation factors), processing systems (post harvest factors), storage conditions, processing, preparation of the beverage and taste of the consumer (*Moreno et al., 1995).* Coffee quality is of critical importance to the coffee industry. Quality coffee is a product that has desirable characteristics such as clean raw and roasted appearance, attractive aroma and good cup taste (Behailu *et al*., 2008).

However, in Ethiopia the quality of coffee produced by farmers has been deteriorating from time to time. Moreover, factors that determine coffee quality are genotypes, climatic conditions, and soil characteristics of the area, agronomic practices, harvesting methods and timing, post harvest processing techniques, drying grading, packing, storage conditions and transporting, all contribute either exaltation or deterioration of coffee *(Behailu et al., 2008).* Similarly, (Damanu 2008) reported coffee quality as a combination of the botanical variety, topographical conditions, and climatic conditions and the care taken during growing, harvesting, storage, exports preparation and transport. Botanical variety and topographical conditions are constant and dominate the inherent characters of a coffee where as other factors other than climatic conditions can be influenced by human being and it is a key factor in determination of the end quality of a green coffee. Furthermore, improper systems of harvesting, processing, storage and transportation are responsible for the wide spread failure to maintain the inherent quality of coffee produced in Ethiopia (Alemayehu *et al*., 2008).

2.1.1. Genetic factor

The coffee genus includes more than one hundred different species between which a large variation in terms of chemical composition is observed Coffee produced from *C. arabica* is known to have a good quality *(Leroy et al., 2006).* This characteristic is clearly established for classical varieties like Caturra, Mundo Novo, and other pure lines obtained from pedigree selection. (Walyaro, 1983) showed the presence of large inherent difference among genotypes for bean and cup quality attributes also observed in which variation for cup quality character among varieties and crosses of Arabica coffee. Based on organoleptic evaluation, introgressed lines of Arabica were found to produce good beverage quality (BQ) that was similar to the non-introgressed standard *(Lorey et al., 2006)*. SL 28 had big sized beans (46 %AA) and excellent cup quality, while catura and rume Sudan had small sized beans, lower cup quality and chemical content or the BQ
The worlds' best quality coffees such as Harare, Limu, and Yirgacheffe (ITC, 2002) are produced in the eastern, south western and Southern parts of Ethiopia, respectively. Likewise, farmers, consumers and agricultural development agents reported the presence of considerable cup quality variation among different arabica coffee genotypes grown in

north western Ethiopia (Yigzaw, 2006), thought not yet characterized for use and conservation in the region.

The most striking association and identification for coffee is its point of origin. The more one knows about the coffee's origin, the more confident one can be about its uniformity and properties. That is the respective details about the coffee's origin are, country of origin, state or region where grown, port of embarkation, the name of the mille exporter, the name of the grower, and the location of the grower's plantation (Mekonen 2009).

2.1.2. Ecological factor (Climatic factor)

The environment has also a strong influence on coffee quality *(Decasy et al., 2003).*
Altitude, daily temperature fluctuations, amount and distribution of rainfall and the physical and chemical characteristics of the soil are very important factors. Climate, altitude and shade play an important role through temperature, availability of light and water during the ripening period *(Decasy et al., 2003).* Rainfall and sunshine distributions have a strong influence on flowering, bean expansion, and ripening *(Harding et al., 1987)*.The slowed-down ripening process of coffee berries at higher elevations (lower air temperatures), or under shading, allows more time for complete bean filling *(Vaast et al., 2006),* yielding beans that are denser and far more intense in flavor than their neighbors grown at lower altitudes (or under full sunlight). The slower maturation process should therefore play a central role in determining high cup quality, possibly by guaranteeing the full manifestation of all biochemical steps required for the development of the beverag quality *(Silva et al., 2005).* For instance, chlorogenic acids and fat content have been found to increase with elevation in *C. arabica (Bertrand et al., 2006).* Besides the beneficial effect of longer duration of the bean-filling period, a larger leaf area-to-fruit ratio (better bean-filling capacity) may also be linked to superior cup quality *(Vaast et al., 2006).*
The role of soil types has been well studied and it is generally admitted that the most acidic coffee quality is grown on rich volcanic soils *(Harding et al., 1987).* The perceived acidity of coffee brews has always been recognized as an important attribute of coffee

quality. Acidity is typically a highly valued quality especially in Central American and some East African coffees (Yigzaw, 2005). Sourness, however, is an extreme of acidity and can be considered as defect. Acidity has been correlated with coffees grown at very high altitudes and in mineral rich volcanic soils. On top of this Yigzaw (2005) reported that if other factors are kept constant, better quality coffee can be found at higher altitude while low land coffee were found to be somewhat bland, with considerable body. Moreover, coffee from high altitude areas was more acidic, with better aroma and flavor. Woelore (1993) reported that for Ethiopian conditions an underwater fermentation technique and the time for fermentation for different agro-ecologies are recommended. According to the author mucilage degradation washed at the first, second, third, or after the third day from pulping in the altitudinal range 1200 m and below, 1200-15000 m, 1500-1800 m and above 1800 m, respectively, for varying fermentation practices. Woelore (1995) reported that factors such as total rainfall, relative humidity, maximum-minimum temperatures with effect on water vapor content of the air and storage duration, greatly influence storability and quality of stored parchment coffee. Periods of prolonged drought may also result in lower quality beans (Wintgens, 2004). Most of the coffee tasters agree now that there is very little or no difference in flavor at all between the Arabica pure breeds cultivated under similar agro-climatic conditions (Wintgens, 2004).

2.1.3. Pre-harvest (agronomic) factors

(Yigzaw 2005) reported that in South America coffee grown with heavy application of nitrogen fertilizer had poorer, lighter and thinner quality than that from unfertilized fields. Excess nitrogen increases the caffeine content, resulting in a more bitter taste of the brew. The caffeine and chlorgenic acid contents of the beans are not affected by the levels of phosphorus, calcium, potassium and magnesium in the soil (Wintgens, 2004). Lack of zinc will lead to the production of small light grey-colored beans, which will produce poor liquor. On the other hand; magnesium deficiency had an adverse effect on cup quality. High concentration of calcium (>0.11%) and potassium (>1.75%) in the beans is associated with a bitter and “hard” taste. (Wintgens 2004) reported that the use of decomposed coffee husk at a rate of 10 ton ha^{-1} (4 kg $tree^{-1}$ on dry weight basis) was found to be superior in terms of yield performance of coffee trees on the other hand, there is no correlation between the phosphorus content and the physical and organoleptic quality of the bean on the contrary, repeated application of elephant grass or livestock manure resulted in an increased percentage of undesirable brown-colored bean and, thus, poor roasting characteristics. This effect was associated with a magnesium deficiency induced by the high potassium content of elephant grass as well as high concentration of potassium and calcium in manure. Good growth conditions (weed control, appropriate planting density and pruning) usually have a positive effect on bean size and flavor (Wintgens, 2004).

2.1.4. Post harvest factors

Coffee processing is the method converting the red cherries of the coffee plant into the parchment coffee. It is a critical operation undertaken with great care as quality could be enhanced or compromised in the course of processing (CAB International, 2009). Coffee is processed by two widely known methods; dry and wet methods. The methods of coffee processing in Ethiopia are sun-drying of unpulped 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). Sun dried coffee accounts for about 76% of the total coffee marketed in Jimma zone. Although washed coffee fetches relatively good price for farmers, its production is limited due to lack of processing facilities, labor shortage with regard to picking up the red cherries, and fluctuating 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 sun dried coffee 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 method 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).

2.1.4 .1. Dry processing

The dry processing method is the standard method of processing Arabica coffee. It is the simplest to use or relatively more straightforward and usually more economical. However, it produces coffee of inferior quality (Russell, 2008). Improved sun-drying where coffee is dried on raised drying beds is advocated for improved quality *(Museb et al., 2007)*. Sun-dried coffee is of particular interest to environmentally minded buyers because it requires fewer resources**.** Natural drying is by far the key stage in coffee post-harvest processing. During this process, the product is spread on surfaces such as cement or brick terraces, bamboo and sisal mats, raised tables covered with wire mesh or fish farm netting, (News Release, 2008**).**

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 *(Museb et al., 2007).* Cherries are 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.

2.1.4 .2. Wet processing

The second method is the wet processing method in which the fresh red cherries are processed in three stages i.e. removals of the pulp and mucilage, fermentation and washing, and drying of parchment coffee (CFC, 2004). 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 processing 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 coffee is aromatic with fine acidity and some astringency, while dry processed Arabica coffee is less aromatic but with greater body. In general, washed coffee carefully prepared and handled, is clean in flavor and free from undesirable elements (Clifford, 1985).

2.1.4 .3. Drying

In this stage, the moisture content of mass or wet pertinent coffee should be reduced from 60 to 53%, which is fairly done, in either a draining to be wet or on dry. Alternatively, the coffee mass can be left in the sun for two or three days and stirred frequently, when the moisture content can reach 45 %(ICO, 2010). Drying is always a delicate operation in the processing carried out; there can be a disastrous effect on quality as regards both appearance and brew characteristic. Drying of coffee comprises a so called wet stage, below 30% (Subedi, 2010). The two additional intermediate stages in parchment coffee the ‘white’ stage, when the moisture content is reduced to 30% but which must be carried out slowly in the shade to prevent cracking or breaking of the parchment cover of the beans, and the ‘soft’ black stage where the moisture content is reduced from 30 to 23%, but which must be carried out in the presence of sunlight that is natural (sun drying).

2.1.4 .4. Sun drying

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 flavor 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 flavor 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).

2.1.4 .5. Artificial drying

Artificial dryer is a modern concept in coffee drying technology. It is the drying method in which both high temperature processes and natural air or low temperature drying procedures are combined in an attempt to provide a high quality product as compared to using only high temperature drying.

Artificial drying is also largely used, since it is becoming more and more difficult for large estates to dry coffee naturally. Again, care has to be taken with the drying conditions, especially with the higher qualities.

The high temperature drying stage is used to reduce coffee moisture contents from approximately 60% w.b. to 25% w.b. (or less), so that natural air drying can be successfully used to complement the drying by further reducing the moisture content of the product to safe limits (Dalpasquale, 1984)

Harvesting

⇩

Sorting and cleaning

⇩

Pulping

⇩

Fermentation

⇩

Washing

⇩

Cleaning

⇩

Skin drying (to prescribed Moisture content)

⇩

Sun drying ⇔ mechanical drying

Source: Mirna *et al., 2003*

Fig 1.wet processing coffee flow chart

2.1.4 .6. 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 (Lowr *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).

2.1.5 Packaging

One of the most important factors in producing the best cup is the availability of truly fresh coffee. Often the methods and materials used in whole bean coffee packaging are overshadowed by the roasting process, and not looked at as a major factor in actual and perceived quality of specialty roasted coffees.

In the specialty industry both retailers and consumers alike need to be not only pleased with the taste of freshness, but equally pleased with the feel and presentation of the packaging as well. The best coffee in the world that is packaged in a can or plastic jug does not display a commitment to freshness and quality. Every aspect of quality and product, including the packaging, determines if a coffee is specialty coffee.

Type of pack

The followings are types of pack and packing methods:

2.1.5 1.Cane

The oldest type of commercial pack is the vacuum-packed metal can (i.e. tin-plated steel with lacquer covering). cans have considerable advantages for packing coffee in that they fulfill a number of useful criteria, notably impermeability to water, air and volatile compound egress or ingress; furthermore they can be directly lithographed without need for labels.

The total headspace should include, the internal pores of the coffee, which at a porosity of 0.49 provides an additional volume of 0.49x1.4=0.69ml per gram of coffee. These pores will contain both CO_2 that is being released and perhaps also occluded the sorbed oxygen.

Measurement of the in-pack percentage at any stage is of value (provided that on flushing with nitrogen has ever taken place), since this will have been associated with the oxygen content in the ratio 79:21(except that it is believed that a small percentage of nitrogen is associated with the evolved CO_2). A comparison with the direct oxygen content will indicate the adsorption or reaction with the roast coffee.

Canes may also be used for holding roast and ground coffee in an inert gas atmosphere. The usual procedure in this case is first to apply a vacuum (which need not be light), and release to a supply of inert gas such as nitrogen. On order, however, to prevent excessive pressure in the cane, it will be necessary to degas the coffee to a much lower level than for high vacuum packing. Alternatively, a relatively low vacuum can be applied to the gas-pursed cane before finally closing.

2.1.5 2.Hard packs of laminates

As an alternative to the cane, so-called ‘hard’ or ‘shape-retentive’ packs of flexible laminated materials shaped in bags have been developed. These packs are called ‘hard’ since on application of a high vacuum after filling and sealing, the material collapse on to the coffee to form a ‘brick’ hard to the touch. Any substantial evolution of CO_2 within the bag, or ingress of air through leaks, will render the bad ‘soft’ and is an undesirable condition. ‘Softness’ does not imply any deterioration of the account, but may well be perceived by the consumer as such.

The bag materials consist of laminates usually of about three different layers, of which aluminum foil is usually the central for moisture ingress protection, with a heat-sealable inner layer of plastic material such as polyethylene; there is a recommended use of PETP at 12μm thickness, aluminum at 12μm and LDPE at 70μm. the sealed filled bad is then usually placed within a closely fitting cardboard box for retail sale.

The vacuum employed just prior to sealing is similar to that used for canes. In such pack, however, the available headspace for CO_2 evolution is much less, so that for packing 1lb of coffee, a package volume of 930ml might be used (instead of 1080ml). Furthermore, it is not longer permissible to allow the internal pressure on storage to rise to atmospheric pressure or beyond.

These kind of packs are, however, somewhat more susceptible to leakage than vacuum-packed canes, because of the potential for ‘pin-holes’ in the laminates and any imperfections at the seal.

2.1.5 3.Soft or ‘pillow’ packs

These packs (also called pouches) are of the same kinds that have been described for use with roast whole been, and the same considerations apply. The packs are described as ‘soft’ since no vacuum is used, and the reduction of the oxygen content out by use of as efficient inert flushing techniques as possible.

Fig 2. Coffee quality cycle

Source:http://www.mpechicago.com/coffee/TechInfo/PDF/RoastersGuildRetreatPresentation

2.1.6. Storage

The raw coffee should be stored in dark areas at low temperatures and relative Humidity Under optimum conditions, dried fruits can be stored for up to 4 month.If the organic product is being stored in a single warehouse together with conventional coffee mixing of the different qualities must be avoided.

Time of coffee in storage (TCS134): According to Anuwar,(2010) storing coffee for more than four months reduces coffee quality 0.163 times than storing coffee for less than four months Van der Vosse (2009) reported that storing dried parchment coffee for more than six months resulted in woody flavor, which lowers quality. Wintgens (2004) further indicated that green coffees stored for a longer period described as ‘aged’ may suffer a loss of their acidity. Length and condition of bean storage also affect cup quality (Yigzaw, 2005). Long time storage under high relative humidity and warm conditions increase bean moisture content and consequently reduce quality in terms of raw and roasted appearance as well as liquor.

Significant defects can also arise as a result of insufficient drying and / or storage conditions as it is the drying process that prepares beans for processing later on as well as storage. When beans are insufficiently or unevenly dried a decrease in cup quality can occur much more rapidly than with beans that have undergone an ideal drying process. Stirling, 1974 shows a rapid decrease in cup quality level with increasing storage time from 6 to 18 months given various moisture contents. The decline in cup quality in wet coffee is due to mold and bacteria as molds and bacteria grow best in moisture rich environments and cup characteristics change as a result of bacteria and mould utilization of sugars in the coffee bean for metabolism recommend a bean moisture content of 10 to 12% before packaging and storage.

One key aspect of coffee storage is bean respiration. Every 24 hours an average of 4.4 milligrams of CO_2 are produced by 100 grams of coffee beans and the 96 calories of heat produced by the 4.4 mg of CO_2 will raise the temperature of the beans .25$_o$ Celsius.

A high respiration rate, in combination with heat generation, can cause a loss of weight and dry material in the bean as well as bean fat decomposition which plays a key role in the aroma of the cup. (Scheidig, 2007)

Storage operations are important from the point of view of ochratoxin A (OTA) prevention and quality assurance. The 'time' element involved in storage operations provides an opportunity for microbiological and biochemical processes to lead to quality deterioration if conditions of storage – particularly temperature and relative humidity – permit.

Prevailing climatic conditions in most coffee producing countries – high temperature and humidity – mean that poor storage management is an important factor to be considered in preventing OTA contamination of coffee.

Storage conditions, including both facilities and practices, are often worse when storage occurs in upstream steps by small-scale farmers and traders. Those who are responsible for promoting safe handling of coffee throughout the chain must be aware of where the main problems lie, and advise on realistic and holistic approaches to address them.

An important recommendation for safe storage is to ensure that products accepted into storage are sufficiently dry (for coffee beans this is around 11-12.5% mc on a dry weight basis). In several countries regulations guide and limit the maximum moisture content of coffee in the domestic marketing chain. The moisture content of dry cherry might be slightly higher – between 11-12.5% - without supporting mould growth and ochratoxin formation Lingle, 1986; Wintgens, 2004).

2.1.7. Transport

Storage and transport pose similar risks to coffee quality. Re-wetting of beans due to leaky tarpaulins or high humidity inside hot containers standing for long periods in tropical ports, can result in the coffee developing mouldy or musty flavours. Special techniques for handling bulk or bagged green beans for container shipping are now well known.

2.2. Coffee quality

Quality is a trait difficult to define. According to any dictionary, it is an inherent or distinguishing characteristic. The International Organization for Standardization (ISO) describes quality as the ability of a set of inherent characteristics of product, system or process to fulfill requirement of customers and other interested parties (ISO, 2007). These inherent characteristics can be called "attributes".

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

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

• **At the roaster level**: coffee qualities depend on moisture content, stability of the characteristics, origin, price, biochemical compounds and organoleptic quality. It should be noted that each consumer market or country may define its own organoleptic qualities;
• **At the consumer level**: coffee quality deal with price, taste and flavor, effect on health and alertness, geographical origin, environmental and sociological aspects (organic coffee, fair trade, etc) (Lorey *et al.,* 2006).
The following is a list of quality characteristics with minimum and maximum values for raw coffee, that are usually required officially or by importers.

2.2.1. Moisture content

Moisture is an important attribute and indicator of quality. A market survey conducted by (APROMA in Europe in 2005-2006) for the common fund for commodities concluded that for Robusta coffee beans the most important defect for a trader or a roaster is the moisture content. A high moisture content of the beans is a lost of material and leads to physical and sensorial defects. If the beans are too wet they will mould easily during storage. If the beans are too dry they will loose flavor.

2.2.2. Physical quality

Since October 1st, 2002, the International Coffee Organization (ICO, 2004) implemented a Coffee Quality Improvement Program (CQP) with recommendations to exporting countries. It is not recommended that coffee be exported with the following characteristics: for Arabica, in excess of 86 defects per 300g sample (New York green coffee classification/Brazilian method, or equivalent); and, for Robusta, in excess of 150 defects per 300 grams (Vietnam, Indonesia, or equivalent classification). Also,
ISO (2004b) has established a standard (ISO 10470) that describe defects as:

- ❖ Foreign materials of non-coffee origin;
- ❖ Foreign materials of non-bean origin, such as pieces of parchment or husks;
- ❖ Abnormal beans for shape regularity/integrity;

- ❖ Abnormal beans for visual appearance, such as black beans;
- ❖ Abnormal beans for taste of the cup after proper roasting and brewing.

Bean size is an important factor since price is related to the coffee grade (small beans of the same variety can bring lower prices). Roasting should ideally be carried out with beans of the same size. When unevenly sized beans are roasted, the smallest tend to burn and the largest tend to be under-roasted, this affects the visual appearance of the beans and the cup quality.

2.2.3. Organoleptic quality

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

2.2.4. 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 extenal compounds independent of the chemical composition of coffee beans. The level of pesticide residues is usually low in coffee (FDA, 2006). Ochratoxin A (OTA) is a toxic mycotoxin. Mycotoxin can be produced by several mould

species and can be found particularly in cereals. In coffee, OTA is produced by *Aspergillus niger, A. carbonarius and A. ochraceus*. It has been shown to cause kidney damage and tumours in test animals. It is classified as possibly carcinogenic to humans.
In terms of chemical compounds present in coffee beans, several of them are known to have consequences on health (Eshetu and Girma, 2008).

2.2.5 Coffee Quality Assurance

Quality assurance starts in the coffee field, where good agricultural and transport practices are essential to develop and preserve the natural quality of the green beans from farm to the cup. 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. moldy, 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, preventive measures and precautions taken to ensure that the quality of coffee attained and maintained day after day (Prodolliet, 2004).

2.3. 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 define 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 -flavors" (Wintgens, 2004).

2.3.1. 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. 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 % and 25 %, 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 % 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)

2.3.2. Sensory evaluation

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

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

• A spacious room, equipped with adequate illumination, a sample roaster, a grinder, a cupping table, cups and spoons.

• A methodology, describing precisely the roasting conditions, the particle size after grinding, the dosage of coffee in the brew, type and temperature of water used to prepare the brew, the way to taste (aroma assessment, removal of floating particles, sucking, use of reference samples), the type of test, the number of cups tasted, etc.

• A vocabulary, defining all the sensory attributes to be evaluated and a well trained panel.

2.3.2.1. Raw analysis

Physical defects

Defects are manually separated according to their type. The number of visually defective beans plays a large role in how the coffee is graded.

Primary defect (count): fully black beans, full sour beans, fungus attacked beans, broken beans, and insect damaged beans, pod/husk and foreign matter. As defect count system ranges 1 to 10 where 1= >15 defects, 2=11- 15 defects, 4= 7-10 defects, 6=5-6 defects, 8=1-4 defects, 10=0 defect by counting the defect (ECX).

Secondary defect (weight): partial black, partial sour, floter ,immature, foxy, under/over dried beans, faded /starved beans and stinkers, faded/coated beans and light/starved beans as (ECX, 2009) standards. 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). The coffee it ranges from 1-10 where 1= >14%, 2= <14%, 4= <12%, 6= <10%, 8= <8%, 10= <5 %

Shape and make: this refers to the structural make up of the different kinds of beans. The region where the coffee is growing, nature, variety and the production system governs the shape and make of the beans. There are a variety of structures: Round, oval, elongated, bourbon, flat, etc and each region has got a distinct bean shape size and appearance. Finally taking their representativeness to the origin one can easily classify and grade the shape and make of the coffee.

The analysis is undertaken by recording the attributes that determine the quality of the coffee beans. Shape uniformity and size of the beans i.e., if there is pea berry, round shape, broken bean shelled beans will be evaluated. The coffee it ranges from 1- 10 where 1=small, 2=fair, 4= average, 6=fair good, 8=good, 10=very good

***Color*:** well – processed coffee has an attractive raw color. Mostly, Bluish color is taken as standard and on basis of this we classify whether the color deviates from this we classify whether the color deviates from this bluish color or not. And these color are like grayish, greenish, faded, brownish and so on are graded accordingly.

The overall appearance (bluish, grayish, greenish faded, whitish etc.) is analyzed in comparisons to the standard. For better coffee (sample), the blue to grayish signifies the most desirable attribute of appearance. The color of the bean will be evaluated by visual inspection method ranging from 0 to 5 where, 0=white 1= Faded, 2=coated, 3= Greenish, 4= Grayish, and 5= Bluish.

Odor*:* this measurement is briefly stated under the unwashed coffee title. The prominent odor perceived in washed coffee is stinker, moldy, grassy and low land odor. Generally the good washed coffees have the following characteristics. Color: Blue or Blush – green – with white & silver – skin and center cuts. Drying: even drying, not mixed, uniform in color Defectives: few in number.

It approves whether the coffee is contaminated with bad odor of foreign material. And it ranges from 0 to 5 where, 0=Strong, 1= Moderate, 2=Light, 3=Trace, 4= fair clean and 5=Clean.
Therefore, the parameters used for grading are defect, shape & make, color & odor which are important in the green evaluation.

2.3.2.2. Cup quality

Cup quality, often referred as drinking quality or liquor quality, is an important attribute of coffee and acts as yardstick for price determination (Agwanda et al., 2003). For this, the assessment of sensory evaluation can be done organoleptically by panel of experienced coffee tasters (Van der Vossen, 1985) and is determined based on the level of acidity, body, and flavor of the brew (Raju *et al.,* 1978; Walyaro, 1983; Morenu *et al.,* 1995). Walyaro (1983) recommended this as a sufficiently reliable method for use as a basis of selection in quality improvement program. Similarly, Owuor (1988) observed close similarity among liquorers in ranking various cup quality characteristics of the cultivar, indicating that any one panel could be relied on selection for cup quality.
Thus, coffee cupping is a technique used by cuppers to evaluate the flavor profile of a coffee, to understand minor differences between growing regions, to evaluate coffee for consistence and defects to subsequently make buying decision and to crate coffee blend (EAFCA, 2008).

This consists of six steps, to evaluate a coffee's fragrance, aroma, nose, after taste, and body (Lingle, 1986). 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. 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).

Cup 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 cup 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. 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).

If there is problem during roasting, trained panelists will assess the organoleptic quality. Tasting will be carried out once the beverage cooled to around 60^0c (drinkable temperature) ranges from 0 to 15 where, 0=>3 cup defect, 3=3 cup defect, 6=2 cup defect, 9=1 cup defect, 12= F. clean, 15=clean(ECX 2009)

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 flavor, 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). According to the ECX coffee contract 2010 the points given to acidity ranges from 0 to 15 where, 0=Not Detected,
3 =Lacking, 6=Light, 9=Medium, 12=M.pointed, 15=Pointed.

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, flavor is the coffee's principal character, the mid-range notes, in between the first impression given by the coffee's first aroma and acidity to its final after taste. It 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 flavor 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). According to the ECX coffee contract 2010 the points given to body ranges from 0 to 15 where, 0=Not Detected 3 =thin, 6=Light, 9=Medium, 12= M. full and 15= full

Flavor: it is the combination of body and acidity. Flavor 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). The flavor obtained in a coffee cup is the result of multiple aromatic compounds present in the coffee (more than 800 in the roasted coffee). Assessment of Measurement of the composition in 800 aromatic compounds present in roasted coffee is not a viable method to assess coffee organoleptic quality, development of indirect predictors of coffee organoleptic quality is underway (Leroy *et al*., 2006) though it was not the objective of this study. These predictors include quantification of chemical compounds present in green coffee (sugars, lipids, proteins, chlorogenic acids, and methylxanthines) via the traditional wet chemistry method and indirect methods like Near Infrared spectra (Bertrand *et al*., 2005). The development of such easy to use and efficient tools should allow large scale phenotyping; a key component towards the implementation of breeding strategies for organoleptic quality in coffee (Bertrand *et al.,* 2005). According to the ECX coffee contract 2010 the points given to flavor ranges from 0 to 15 where, 0=Not Detected 3 = Commonish, 6= Fair, 9= Average, 12= F. good and 15= good

2.4. Coffee Grading

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 (Endale, 2007). 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 (raw).Cup test is based on roasted coffee analysis (chemical process) by which aroma; acidity, body and other flavor components are tested.

According to Ethiopian Commodity Exchange (ECX) grading system currently applied in the country since 2009. The ECX Contracts of grading factors of unwashed coffee is categorized in to two: the raw value and cup quality value. The raw value scores 40%, Primary (count)(10%), Secondary (wt)(10%),Shape & Make (10%) , Color (5%) ,Odor (5%) and the cup quality value scores 60% cup cleanness =15%, acidity=15%, body=15%, flavor=15%).

2.4.1. General Requirements

The moisture content of washed 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 (ECX, 2009).

Table 1.Grading factors for washed and prepared coffee

Grade	Total Value (Raw Value + Cup Quality Value
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
Undergrad coffee	
Grade UG	15-19 (Total Value)

Source: ECX Coffee Contracts (2010)

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) Commercial Coffee Grading

General Requirements; Under Grade (UG) should fulfill sound bean % by weight <50% and flavors value score fair.

The quality of the final flavored product is checked with a sensory evaluation technique known as "cupping" (FAO, 2010).

Specialty Grading in the ECX: for 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).

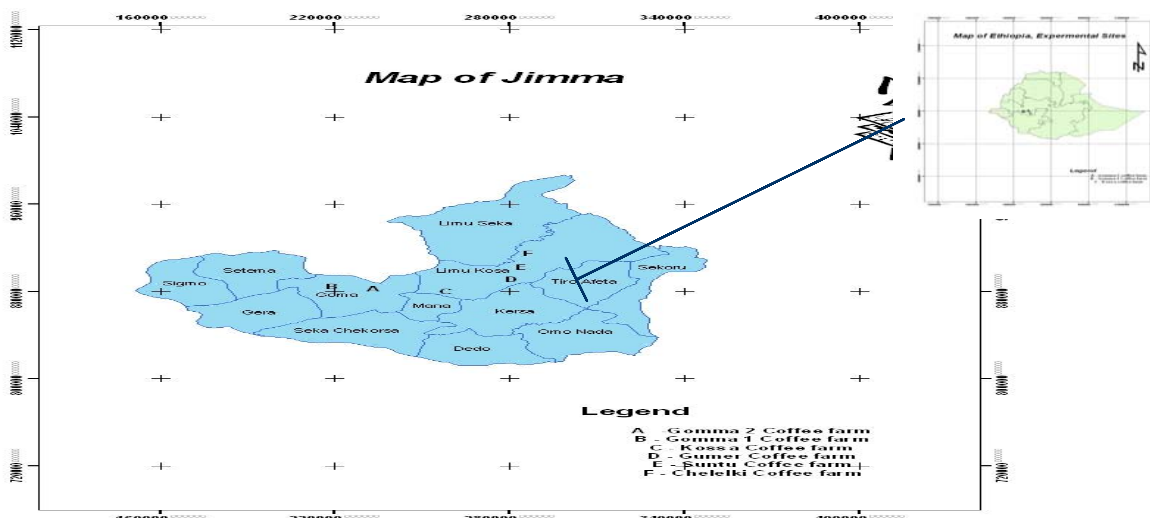
This adds an additional level of quality assurance for these two grades of coffee and ensures specialty coffees are identified and separated from the commercial grade coffees. These grade classifications will accompany with the regional and origin classifications (geographic indications). The current ECX system collects coffee in its regional receiving warehouses for inclusion into their export system. Coffee is assigned one of 10 regional indications for washed coffee or 11 for natural, and given a grade of 1-9, or UG (under grade) based on physical grading and basic cup evaluation (Reuters, 2009).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The processing experiments were (20) carried out in at Limmu Woreda, Jimma Zone, under Limmu Coffee Plantation (LCP), specifically at Suntu site which is located between 89°30’N latitude and 36° 57’E in Southwestern part of Ethiopia with a total area of 2,092ha. The altitudinal range of the Woreda is between 1600 and 1800 m above sea level. The area has an average annual rainfall of 1626 mm and the mean annual average temperature of 30 °C,. The Woreda is 431 km far from Addis and 75 km from Jimma town (LCP) 2009/2010

The laboratory analysis was conducted at Ethiopia commodity exchange (ECX) coffee cupping laboratory which is located in Addis Ababa specifically at Saris.



Source: Limmu Coffee Plantation (LCP) 2009/2010 (Unpublished annual report)

Fig 3. Map of Ethiopia and Experimental area

3.2. Experimental Factors

The experiment had two factors, namely: temperature and moisture content. The first factor (drum temperature) comprises 60^0C; 70^0C, 80^0C, 90^0C and sun drying on the bases of drum temperature it ranges from 60^0C to 90^0C. The maximum drum temperature is 60^0C and the minimum is 90^0C. The second factor (moisture content) comprises 16%, 21%, 26% and 40% on the bases of different company practice 16%, 21%,26,this are Limu coffee plantation practice Suntu, kosa and Goma 2 respectively the remaining 40% are Gemadro practice

3.3. Experimental Design

The experiments were laid out in a 4x5 factorial design arranged in complete randomized design CRD with three replication= a total of 60 experimental units. Randomization was held separately and independently for each of the replications where the treatments are assigned completely at random as described by Gomez and Gomez (1984).

The model

Model: $X_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$

X_{ij} =ith observation at the i^{th} level of temperature and the j^{th} level of moisture content

μ = is the overall mean response

α_i = effect of the i^{th} level of the first factor (temperature) (i = 1, 2, 3,4,5)

β_j = the effect of the j^{th} level of the second factor (moisture content) (j= 1,2,3,4)

$(\alpha\beta)_{ij}$ = the interaction effect of the j^{th} (temprature) and j^{th} (moisture content) level

ε_{ij}= The random error component

3.4. Experimental Procedure

Before starting the experiment, it was desirable to assess the accessibility of the experimental materials to undertake both the field and laboratory activities

3.4.1. Farm Processing

Primary processing was done immediately after harvest. Red ripe cherries harvested (hand picked) from Limmu coffee plantation Suntu site and cherries are sorted cleaning; (leaves, sticks, unripe fruit and those in advanced ripening state) the beans were pulped using the pulping machine. This operation is the key difference between the dry and the wet methods, since in the wet method the pulp of the fruit is separated from the beans before the drying stage. The pulping was done by a machine which squeezes the cherries between fixed and moving surfaces. The flesh and the skin of the fruit were removed and carried out by water on one side and the beans are carried by water to the enclosed in their mucilaginous parchment covering, on the other. The bean where moved in to the demucilager during pulping the un pulped cherries went to the re passer disk for repulping. After the mucilage is removed the beans are allowed to stay the fermentation tanks. Then the bean was soaked and washed in (about 100 L water for 10 kg of coffee). Finally pre-dried (sun drying) in raised bed with in skin drying table until the requred moisture content is obtained to 16%, 21%, 26% and 40 % dry bases. the first moisture content (16%), on the first processing day then the second moisture content (21%), on the second day, the third moisture content (26%), on the third day and finally the last moisture content (40%) on the fourth day. Then the parchment coffee cherry were dried in coffee dryer with the different drum temperature (60^0C, 70^0C, 80^0C, 90^0C) and the cherry is dried until the moisture content was 11.5% and checked by using moisture tester (Multi grain tester). The sun drying coffee sample was taken from the former one and dried on the skin drying table until the moisture content came down to 11.5 %.

3.4.2. Labeling and packing

Each coffee sample was prepared with 1kg per sample of parchment coffee packed and labeled with plastic bags for proper handling till further quality analysis was made. Finally the samples were brought to (ECX) and then to coffee Quality laboratory found in Addis Ababa. Which is selected because of; the laboratory is well equipped for coffee quality analysis and have well experienced and “Q” certified cuppers/ liquors.

Fig 4. Labeling and packing of the parchment coffee

3.4.3. Quality Analysis

The hulling operation was implemented to release the coffee beans from the parchment. It was done using hulling machine found at ECX laboratory. After hulling 500g wet processed green beans submitted by code to ECX .Green bean physical and cup quality characteristics were evaluated from five samples by three Q certified professional coffee tasters. Coffee quality analysis is carried out under coffee laboratory conditions using liquors taste evaluated for physical and sensorial factors. Each sample was coded according to the standard procedures used for washed coffee raw and cup quality evaluation and grading as per ECX (2009). The raw value scores 40% (primary defect = 10, Secondary defect =10, Shape & Make 10%, Odor=5% and Color 5% and the cup value scores 60 %(Cup cleanness =15%, Acidity =15%. Body=15% and Flavor = 15 %). The combined effect of raw and cup quality analysis consider accounting comparative sensorial tests describing a scale from (1 to 9) where 9 corresponded to the worst cup and 1 to the best cup in Ethiopian condition ECX (2009). The odor of the whole of the sample was judged by sniffing with nose as close as possible to the coffee. In all factory nuances, particularly any disagreeable odors foreign to coffee was detected and recorded. Odor: The type of odor that a given coffee sample depends on the way coffee is harvested processed and transported. It approves whether the coffee is contaminated with bad odor of foreign material.

3.4.3.1. Raw coffee quality evaluation

The general requirements: the moisture content of washed coffee shall not be more than 11.5% it was checked before the commencement of quality analysis (ECX, 2009).

Sampling: During raw/physical quality analysis, 350g of green bean was used for each sample and their defects,shape and make, color, odor, were measured according to the Ethiopian standard (ES 589: 2001) and these data were evaluated based on green coffee reference chart which is a published Working Draft 4467: 2000 by QSAE identical with ISO 10470: 2004.

Fig 5. Sampling of the parchment coffee

Coding**:** The samples collected from each treatment for the analysis of quality parameters were assigned by the researcher in the field and used for further arbitrary code to avoid individual biasness of the panel, including the researcher.

Fig 6. Coding of the green been

Moisture testing: It is a standard quality evaluating parameter to know whether the coffee can continue for further steps of quality. In the raw analysis moisture testing was done by taking 350g green beans sample to recognize the moisture percentage of coffee samples tested and to make the comparison with the acceptable ranges /standards moisture content (11.5%). The moisture content of each sample bean was measured with a standard moisture tester Multi grain (Dickey joy) certified by Quality and Standard Authority of Ethiopia.

Fig 7. Moisture testing of the green been during laboratory

3.4.3.2.. Roasting

Roasting was undertaken on 100 gm green coffee bean sample using sample- roasting machine of model PROBAT.Werke type Brz.6 at temperature of 150^{o}C-200^{o}C for 6-7 minutes (JARC, 1996). The art of roasting is to develop the bean to the exact, where the flavor is brought to its maximum. To attain such objective the degree of roasting matters a lot and as a standard a medium type /degree of Roasted bean color will be light to medium is a desirable standard.

Fig 8. Sample coffee roasting using four cylinder roasters

3.4.3.3. Grinding

Grinding is a physical change or alternation in form with menaces of reducing the size by crushing, rubbing, grinding, cutting tearing, and any other process that will cause particle size reduction. This is carried out using a standard grinder of model and type Mahlkolig /Conumbia, WLLB in a set of cups (12 gm of powder /ground coffee per cup with a capacity of 240 ml). 12gm of roasted bean (for each cup) grinding using coffee grinder using fine to medium size.

3.4.3.4. 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.

Fig 9. Sample coffee brew preparation

3.4.3.5. Coffee Tasting

The tasting of coffee is a rigorous and disciplined process, done by an expert to evaluate the brew and determine its characteristics. Sensory evaluation was done using four quality criteria: cleanness, acidity, body and flavour; and scoring were based on ECX (2009) standards. The coffee samples were medium roasted and medium ground. The beverage was prepared by brewing 12 g roasted coffee in 240 milliliters of hot water. The coffee brews were evaluated by a panel of three tasters. A team of three expertises experienced and internationally certified Q grader cuppers made this (Appendix fig

2).They participated in a panel for cupping to evaluate the aroma and taste characteristics of each sample. Average result of cuppers used for the analysis. For liquoring 5 cups were prepared which is a total of 300 cup that is (60 X5) by mixing 12g 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). After sitting for three to five minutes, the cap of saturated coffee grounds was "broken" with the bottom of a special cupping spoon and the aroma is evaluated. The cup was then stirred, and any grounds that still float are removed. All this experiment was carried out to assess the major cup tasting parameters like acidity, body, flavor and its cleanliness which are vital to decide the coffee quality (Endale, 2008). Only then was the sample ready to be tasted.

Cup tasting*:* After all the above procedures completed tasting was carried out by 3 cuppers when the liquid (brew) has a palatable temperature and it is an indicator for the cup test. Fragrance: is an odor of the coffee powder only in the cup before mixed with water.

Fig10. Professional coffee tasters of the ECX, cupping for quality evaluation

3.5. Data Collected

3.5.1. Field data

The primary processing activities held in the field was drying days and moisture content

Days to Drying: The length of drying period between date of processing 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 parchment attains 11.5%, it became to be stored until further processing.

3.5.2. Laboratory analysis

Data collected from physical and sensory evaluation was held in coffee laboratory by expert cuppers. Physical quality attributes (defects, Shape and Make, Color, Odor); similarly, cup quality attributes (cup cleanness, acidity, body and flavor) as per ECX (2009).

I. Raw quality evaluation

Physical defects

Defects are manually separated according to their type. The number of visually defective beans plays a large role in how the coffee is graded.

A) Primary defect (count): fully black beans, full sour beans, fungus attacked beans, broken beans, and insect damaged beans, pod/husk and foreign matter.

B) Secondary defect (weight): partial black, partial sour, floater, immature, foxy, under/over dried beans, faded /starved beans and stinkers, faded/coated beans and light/starved beans as (ECX, 2009) standards. 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)

C) *Shape and make:* The analysis is undertaken by recording the attributes that determine the quality of the coffee beans. Shape uniformity and size of the beans.

D) Appearance/Color: The overall appearance (bluish, grayish, greenish faded, whitish etc.) is analyzed in comparisons to the standard. For better coffee (sample), the blue to grayish signifies the most desirable attribute of appearance.

E) Odor: It approves whether the coffee is contaminated with bad odor of foreign material. And it ranges from 1 to 5

F) Total raw value: The sum total of physical quality attributes

II. Cup quality evaluation

A) Cup cleanness: it indicates freeness of the coffee from defects. If there is problem during roasting, trained panelists will assess the organoleptic quality. Tasting was carried out once the beverage cooled to around 60^0c (drinkable temperature).

B) Acidity: to identify the sense of coffee on the tongue strengthens of the coffee

C) Body: it is the mouth fellness of the coffee, ranges.

E) Flavor: it is the combination of body and acidity.

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

G) Total quality: the sum total of both physical and orgsnoleptic values of each treatment used to evaluate the samples in to appropriate coffee grade points.

III. Grading

Green bean coffee samples evaluation and grading for both raw (40%) and liquor (60%) quality was carried out for 60 samples following the procedures of Ethiopian Commodity Exchange (ECX, 2009). The overall standard for raw and liquor quality grades of unwashed coffee Grade range: grade1=91-100; grade2=81-90; grade3=71-80; grade4=63-70; grade5=58-62; grade6=50-57; grade7=40-49; grade 8=31-39; grade 9=20-30; under grade=15-19.

3.6. Statistical Analysis

The data were checked for normality and subjected to Analysis of Variance (ANOVA) and correlation analysis using SAS statistical software (version 9.2, 2009). When ANOVA showed significant differences, mean separation was carried out using Least Significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

4. RESULTS AND DISCUSSION

4.1. Drying Period

The two way interactions effect between moisture content and temperature showed significant differences ($P \leq 0.05$) in drying period i.e. (Table 2). Coffee with an initial moisture content of 16% dried in the artificial dryer whose drum temperature adjusted 90^0C took the shortest drying period (5hr) and the coffee dried under this condition was found to be specialty grade 1.

Next to this coffee dried at 80^0C with an initial moisture content of 16% resulted in the next lowest drying period (7.2 hr) with very good quality coffee (grade 2). The third shorter drying period was (9.23 hr) for coffee dried with initial moisture content 16% at 70^0C and this resulted in a (grade 2). Coffee dried at 60^0C with an initial moisture content of 16% has resulted in a drying period of 11.10hr and has resulted good quality (grade 2). Coffee dried at 80^0C with initial moisture content of 21% has taken 13.76hr to dry. (Table 2) .coffee dried in the sun with an initial moisture content of 21^0C has taken (15.17hr) to dry and drying period of coffee of similar initial moisture content (21%) which is dried at 80^0C but the quality of coffee dried in the sun has lower quality coffee relative with the coffee dried at 80^0C .

Coffee with an initial moisture content of 21% which are dried at 60^0C, and 70^0C have statistically similar drying period 16.92hr and 16hr respectively and the same initial moisture content and temperature of 90 ^{0}C it took (11hr)but the coffee dried at 70^0C has very good quality (2) than the two.

Similarly the result presented on (Table 2) showed significant variations ($P \leq 0.05$) between moisture content and temperature with the initial moisture content of 26 and drying temperature of 90^0C, 80^0C, 70^0C, 60^0C, and sun has resulted in a drying period of 18.1, 20.35, 22.00, 26.17 and 27.25hr respectively but the coffee dried at 60^0C and sun dried has very good quality (2) than others.

The coffee dried with an initial moisture content of 40% and drying temperature of 90^{0}C, 80^{0}C,70^{0}C, 60^{0}C and sun have resulted in a drying period of 32.33hr, 36.25hr, 40.25, 44.58 and 53.77hr respectively but the coffee dried in the sun has very good quality **(**2**)** among the others. The above result supports the findings of FAO (2010), indicating that parchment coffee 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 bean.

Table .2. Interaction among temperature and moisture content using artificial and natural drying methods for mean drying period (hour) of wet processed coffee

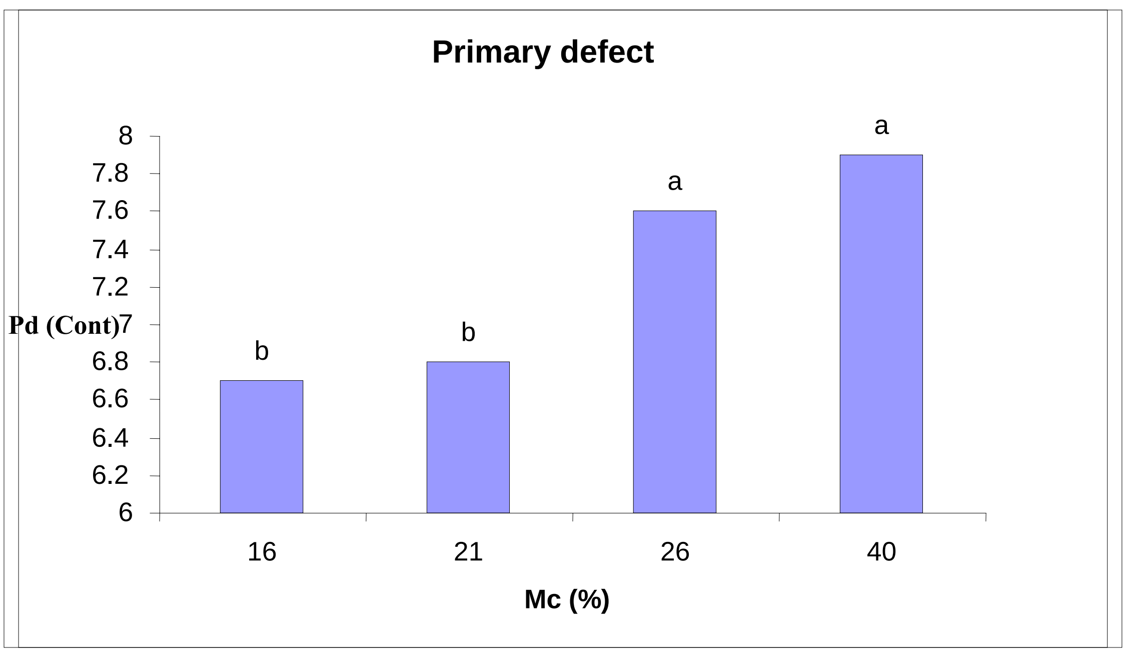
Moisture content (%)	Temperature (^{0}C)				
	60	70	80	90	Sun
16	11^d	9^c	7^b	5^a	12^e
21	16^i	16^h	13^f	11^h	15^g
26	26^m	22^l	20^k	18^j	27^n
40	44^r	40^q	36^p	32^0	53^s
LSD (0.05)	0.43				
CV (%)	1.19				

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

4.2. Primary defects

The raw quality analysis showed significant ($P \leq 0.05$) variation for primary defect counts (fig 10). At moisture content level of 40% and 26% showed statistically similar and the highest mean primary defect score (7.9 and 7.6) respectively and. On the other hand the moisture content level of 16% and 21% resulted statistically similar with the lowest mean primary defect score (6.6 and 6.8) points respectively. This could be related to high moisture content level which induces mold development that may cause discoloration of beans and maximized the primary defects counts.

With regards to secondary defects, shape and make color, odor and cup cleanness there was no significant variation with main and interaction effects (Appendixl table I and II)



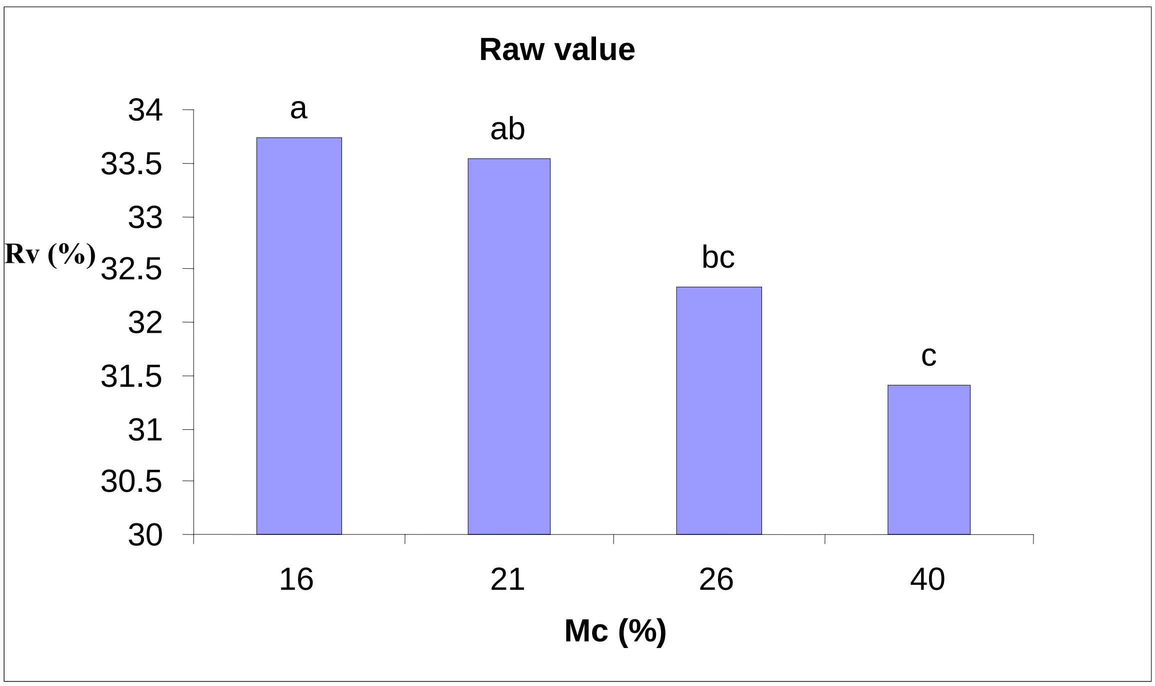
Where: Mc, moisture content and Pd, primary defect

Fig. 11. Effect of moisture content using artificial and natural drying methods on primary defects of wet processed coffee

Bars with same letter (s) are not significantly different at $P \leq 0.05$

4.3. Total raw coffee quality

The raw quality analysis showed significant effect ($P \leq 0.05$) for initial moisture content in raw value (Fig.11) of coffee analysis. The initial moisture content of 16% resulted in the high percentage of raw value (33.73). The coffee dried with an initial moisture content of 21% and 26% has obtained statistically similar mean raw value of coffee (33.53 and 32.33) respectively the coffee dried from an initial moisture content of 40% has obtained the least mean raw value (31.4) this shows that small initial moisture content in drying coffee artificially and naturally results in the highest raw value.



Where: Mc, moisture content and Rv, raw value

Fig. 12. Effect of moisture content using artificial and natural drying methods on total raw value of wet processed coffee

Bars with same letter (s) are not significantly different at $P \leq 0.05$

4.4. Acidity

An interaction effect between the moisture content of the parchment coffee 16% and its drying drum temperature 90^0C produced the highest mean acidity (15.00) and statistically similar mean value (12.00) has been gotten at 16% moisture level and temperature of 60^0C, 70^0C, 80^0C and an open sun drying.

On the other hand, the interaction effect between moisture level of 21% and temperature 70^0C resulted in the medium mean acidity value (12.00). At the same moisture level in an open sun drying medium mean acidity value (11.00) has been observed and at temperature of 60^0C, 80^0C and 90^0C the lowest mean acidity value (10.00) has been observed.

At 26% moisture level and temperature of 60^0C and open sun drying, statistically similar acidity value that is the highest mean value (12.00) is obtained .At the same moisture level and temperature of 70^0C, 80%, 90% statistically different acidity values that is the lowest mean acidity values (11.00, 9.00, 10.00,) are obtained respectively .

At moisture level of 40% and temperatures 60^0C, 80^0C and open sun drying statistically similar acidity value (12.00) is obtained. At the same moisture level and temperatures 70^0C, and 90^0C, similar acidity value that is (11.00) obtained. 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 good preparations, wet processed coffee has high aroma, flavor 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.3. Interaction effects between moisture content and temperature on acidity score values of wet processed coffee

Moisture content (%)	Temperature (^{0}C)				
	60	70	80	90	Sun
16	12^{ab}	12^{ab}	12^{ab}	15^{a}	12^{ab}
21	10^{b}	12^{ab}	10^{b}	10^{b}	11^{b}
26	12^{ab}	11^{b}	9^{b}	10^{b}	12^{ab}
40	12^{ab}	11^{b}	12^{ab}	11^{b}	12^{ab}
LSD (0.05)	3.47				
CV (%)	9.60				

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

4.5. Flavor

The two way interaction between temperature and moisture showed significant (P≤0.05) variation in flavor the highest figure was recorded from the moisture level of 16% and the drying of temperature of 90**^{0}C** with mean value of (15.00) which is a good flavor (Table 4). The lowest (9.00) mean value was recorded from 16% moisture content with 60**^{0}C** drying temperature which is indicating its not good flavor and the moisture level of 16% and the drying temperature of 60**^{0}C**, 80**^{0}C** and sun dried was recorded the medium mean value (11.00) which is considered good flavor. 21%moisture content and the parchment coffee dried under the temperature of, 70**^{0}C,** 80**^{0}C** and 90**^{0}C** was indicated the highest mean value and statically similar. The lowest mean value was recorder from 16% moisture content of parchment coffee dried under the temperature of 60**^{0}C** and sun dried coffee showed mean value of (10.00).

Appropriate post harvest management practice using mechanical drying method could maintain the flavor quality of wet processed coffee. Whereas, the sun dryer with thick layered cherries induced off-flavors of the green coffee beans. The present finding agrees with the report of Endale (2008) who reported that coffee with a better attention during drying resulted in a better flavor. Prodolliet **(**2004) and FAO (2010) also reported that natural coffees present strong body and aroma, mildly acidity and sweet flavor.

Table. 4. Interaction effects between moisture content and temperature on flavor score values of wet processed coffee

Moisture content (%)	Temperature (^{0}C)				
	60	70	80	90	Sun
16	9^{b}	11^{ab}	11^{ab}	15^{a}	11^{ab}
21	10^{b}	11^{ab}	11^{ab}	11^{ab}	10^{b}
26	12^{ab}	12^{ab}	9^{b}	12^{ab}	12^{ab}
40	10^{b}	11^{ab}	9^{b}	10^{b}	11^{ab}
LSD (0.05)	4.02				
CV (%)	12.36				

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

4.6. Total Cup quality

The two way interaction between temperature and moisture showed significant ($P \leq 0.05$) variation in total cup quality. The highest score was recorded at the moisture level of 16% for the coffee dried at temperature of 90$^{\mathbf{0}}$**C** with mean value of (57.00) which is specialty coffee grade (1) .

The coffee dried (Table 5) with initial moisture content of 16% and temperature of 70^{0}C and 80^{0}C, with initial moisture content of 21% and temperature of 70^{0}C, with initial moisture content of 26% and temperature of 60^{0}C and sun dried, and also with initial moisture content of 40% and sun dried have resulted in statistically similar good cup value (grade 2) with cup score (49.00, 50.00, 49.00, 50.00, 51.00 and 49.00) respectively. The coffee dried with moisture and temperature combination of 16% with 60^0C,21% with 80^0C,90^0C and sun,26% with 70^0C, 80^0C and 90^0C, and 40% with 60^0C,70^0C,80^0Cand 90^0C have also resulted in statically similar cup value the lowest grade (3).

Results of the present study are in agreement with the findings of FAO (2002) and Appropedia (2010) , indicating that a good quality wet 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 wet coffee processing can produce high quality coffee and creates a highly preferred coffee compared to un washed indicating that processing does have an identifiable influence on cup taste.

Table 5. Interaction effects between moisture content and temperature on total cup quality score values of wet processed coffee

Moisture content%	Temperature ^{0}C				
	60	70	80	90	sun
16	47^b	49^{ab}	50^{ab}	57^a	49^{ab}
21	45^b	49^{ab}	48^b	45^b	47^b
26	50^{ab}	48^b	44^b	45^b	51^{ab}
40	47^b	45^b	48^b	47^b	49^{ab}
LSD (*P≤0.05)*	8.94				
CV (%)	6.51				

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

4.7. Total Coffee Quality

The two way interaction effects among temperature and moisture content showed significant *(P≤0.05)* variations for total quality attributes of coffee beans (Table 6). Accordingly; the highest mean value of total quality (91.66) was recorded at initial moisture content of 16% and temperature of 90^0C. This value indicates excellent specialty taste, received a “specialty grade 1”. The coffee dried from initial moisture content (16%) at temperature of 60^0C, 70^0C, 80^0C and sun dried produced statistically similar total coffee quality (80,82.66 and 84.66 and 81). Similarly at the same moisture and temperature of 60^0C and open sun drying the lowest mean total quality value (*80.00 and* 81.33) was obtained.

At initial moisture content of 21% and temperature of 70^0C the highest mean value of total quality (82.00) which attains a good total coffee quality. Similarly the same initial moisture content and temperature of 60^0C, 80^0C, 90^0C and open sun drying statistically similar mean value of total coffee quality. These values range in between *79.33* and 81.00.

Table 6. Interaction effects between moisture content and temperature on total coffee quality score values of wet processed coffee

Moisture content (%)	Temperature (^{0}C)				
	60	70	80	90	Sun
16	80.00^b	82.66^{ab}	84.66^{ab}	91.66^a	81.33^b
21	79.33^b	82.00^{ab}	81.00^b	78.33^b	80.33^b
26	83.00^{ab}	80.66^b	76.00^b	77.33^b	82.66^{ab}
40	77.33^b	78.00^b	77.66^b	78.00^b	82.66^{ab}
LSD (0.05)	10.11				
CV (%)	4.04				

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

4.8. Coffee Grading

The two way interaction between temperature and moisture content showed significant differences (*$P \leq 0.05$*) for grade of washed coffee at the study sites (Table 7).Coffee dried with initial moisture content of 16% and temperature of 90^oC resulted in specialty coffee grade (1). This value shows dying washed coffee at high temperature with low initial moisture content results in better quality and this result agree with the findings of (Kessler, 1988) High temperature-short time processing is based on the principle that the temperature dependence of the microbiological inactivation is very much higher than that of the quality changes taking place in the food due to the thermal processing. Hence, HTST-processing has the objective to optimize and reach the best possible quality of the heat treated food product. Important quality parameters are sensory attributes such as color, texture and taste and also nutritional value of the product. On the other hand the same moisture content and the temperature of 60^0C , 70^0C, 80^0C and open sun drying resulted in statistically similar and the highest grading score mean values 2.00 and the same moisture content and the temperature of 60^0C produced lowest grading mean values (2.66) score profiled under grade 3.

The coffee dried with initial moisture content of 21% and at temperature of 60^0C, 70^0C, 80^0C, 90^0C and open sun drying resulted in statistically similar and the lowest grade score mean values ranging from (2.33 to 2.66) this value is included under grade 3.How ever the coffee dried with initial moisture content of 26% and at temperature of 60^0C produced highest grade mean values (2.00) score profiled under grade 2. At the same initial moisture content and temperature of 70^0C, 80^0C ,90^0C and open sun drying statistically similar and the lowest grading score mean values ranging from (2.33 to 3.00) have resulted and this value is included under grade 3 .

At 40% initial moisture level and temperature of 60^0C, 70^0C, 80^0C and 90^0C statistically similar grade value ranging from (2.66-3.00) that is the lowest grade mean value (3) is obtained. And also at the same initial moisture content and open sun drying the highest grading mean value (2.00) is obtained that is included under grade 2.

Table .7 Interaction effects between moisture content and temperature on grade **score values of wet processed coffee**

Moisture content (%)	Temperature (0C)				
	60	70	80	90	Sun
16	2.66b	2.00ab	2.00ab	1.00a	2.00ab
21	2.66b	2.33b	2.33b	2.66b	2.33b
26	2.00ab	2.66b	3.00b	2.66b	2.33b
40	2.66b	2.66b	3.00b	2.66b	2.00ab
LSD (0.05)	1.26				
CV (%)	18.76				

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

4.9. Correlation Studies

The relationship among drying period, raw value and cup value are presented in (Table 8) The simple correlation analysis showed that drying period has significant at (P≤0.05) and negatively correlation with Primary defect (r=-0.39) and raw value (r=-0.3). It had negative but non-significant correlation with Secondary defect (r= -0.09), Shape and Make (r=-0.08), Color (r=-0.18) and Odor (r=0.29). However, drying period showed not significant (P≤0.01) and negative correlation with cup quality attributes; cup cleanses, (r= -0.16) cup acidity (r=-0.04), body (r=-0.06), flavor (r=-0.17), cup value (r=-0.17) and total cup value (r=0.31)) and positively correlated but significant with grade (0.26).

Primary defect was highly significantly (P≤0.05) and strongly correlated with total raw value (r=0.71). It also showed significant (P≤0.05) and positive association with total value (r=0.34) and significant but negatively correlated with grade (r= -0.39).However, primary defect was not significant (P≤0.05) and positively correlation with secondary defect (r=0.23), color (r=0.24) odor (r=0.21) and cup quality attributes cup cleanses (r=0.13) acidity (r=0.02), flavor (r=0.01) and cup value (r=0.02) and also primary defect was not significance and negatively correlated with color (r=0.05) and body (r=0.08)

Secondary defect has highly significant (P≤0.05) and strongly association with raw value (r=0.58). It had positive but non-significant correlation with shape and make (r=0.20), color (r=0.17) and odor (r=0.14); cup cleanness (r=0.03) flavor (r=0.02) and total value (r=0.20). Secondary defect has also not significant (P≤0.05) and negatively associations with the cup quality attributes acidity (r=-0.14), body (r=-0.02), cup value (r=-0.04) and grade (r=-0.20).

Shape and make was significantly (P≤0.05) and strongly correlated with raw value (r=0.36).It had not significant (P≤0.05) and positively associated with color (r=0.25), odor (r=0.09), body(r=0.10), cup value (r=0.02) and total value (r=0.16). Similarly shape and make showed not significant (P≤0.05) and negative correlation with acidity, (r=-0.02), cup cleanness (r=-0.01), flavor (-0.04) and grade (-0.07).

Color is as one of the measure of raw quality, it had highly significant (P≤0.05) and strongly association with odor (r=0.47), raw value (r=0.67) and total value (r=0.50). It was significantly (P≤0.05) and negatively correlated with grade (r=-0.39) It had positive but non-significant correlation with cup cleanness(r=-0.13), acidity (r=-0.15), flavor (r=-0.30) and cup value (r=-0.23).similarly color showed not significant (P≤0.01) and negative correlation with body (r=-0.04). Odor was highly significantly (P≤0.01) and positively associated with raw value (r=0.57). It had not significant (P≤0.01) and positively associated with flavor (r=0.24), cup value (r=0.02), total value (r=0.26) and grade (r=0.12). Similarly odor showed not significant (P≤0.01) but negative correlation with cup cleanness (r=-0.11), acidity, (r=-0.04) and body (-0.09).

Raw value was highly significantly (P≤0.05) and strongly correlated with total value (r=0.50). It also showed significant (P≤0.05) and negatively correlated with grade (r=0.34). It had positively correlated but non-significant with cup cleanness (r=-0.09), acidity, (r=-0.09) flavor (r=-0.16) and cup value (r=-0.08) similarly raw value was not significance and negatively correlated with body (r=-0.06).

Cup cleanness is as one of the measure of cup quality, it had significant (P≤0.05) and strongly correlated with cup value (r=-0.43) and total value (r=-0.40). It had also positively correlated but non-significant with acidity (r=-0.02) and body (r=-0.19). Similarly it had non significant but n negatively correlated with flavor (r=-0.09) and grade (r=-0.26)

Acidity was highly significantly (P≤0.05) and strongly associated with cup value (r=0.83) and total value (r=0.72).It also showed significant and positive correlated with body (r=0.36) and flavor (r=0.47). Acidity was highly significantly (P≤0.01) and negatively associated with grade (r=-0.69).

From cup quality Body was highly significant (P≤0.05) and strongly correlated with cup value (r=0.60) and total value (r=0.49).It had also significance and negatively correlated with grade (r=-0.41). Similarly body with not significant but positively correlated with flavor (r=0.04).

Flavor was highly significant (P≤0.05) and strongly correlated with cup value (r=0.64) and total value (r=0.62). Similarly it had highly significant but negatively correlated with grade (r=-0.60).

Total Cup value was highly significantly (P≤0.05) and positively associated with total quality (r=0.80) and it had highly significant but negatively correlated with grade (r=0.-80). This result may suggest the existence of strong link between cup quality attribute and total coffee quality.

Additionally; coffee grade had highly significant (P≤0.05) and negative correlation with acidity (r=-0.69); flavor (r=-0.60); cup value (r=-0.80) and total value (r=0.89); similarly coffee grade had significant and positively correlated with drying period (r=0.26). It had also significant and negatively correlated with primary defect (r=-0.39); color (r=-0.39) raw value (r=-0.45) and body (r=-0.41).It had not significant and negatively associated with secondary defect (r=-0.20); shape and make (r=-0.07) and cup cleanness (r=-0.26). However coffee grade was not significant but positively associated with odor (r=0.12).

Table 1.8 Pearson Correlation Coefficients of coffee quality parameters

	DP	PD	SD	SAM	COL	OD	RQ	CC	ACD	BOD	FLA	CQ	TQ	GR
DP	1	-0.39*	-0.09^{ns}	-0.08^{ns}	-0.18^{ns}	-0.29^{ns}	-0.3*	-0.16^{ns}	-0.04^{ns}	-0.06^{ns}	-0.17^{ns}	-0.17^{ns}	-0.31^{ns}	0.26*
PD		1	0.231^{ns}	-0.05^{ns}	0.24^{ns}	0.21^{ns}	0.71**	0.13^{ns}	0.02^{ns}	-0.08^{ns}	0.01^{ns}	0.02^{ns}	0.34*	-0.39*
SD			1	0.20^{ns}	0.17^{ns}	0.14^{ns}	0.58**	0.03^{ns}	-0.14^{ns}	-0.02^{ns}	0.02^{ns}	-0.04^{ns}	0.20^{ns}	-0.20^{ns}
SAM				1	0.25^{ns}	0.09^{ns}	0.36*	-0.01^{ns}	-0.02^{ns}	0.10^{ns}	-0.04^{ns}	0.02^{ns}	0.16^{ns}	-0.07^{ns}
COL					1	0.47**	0.67**	0.13^{ns}	0.15^{ns}	-0.04^{ns}	0.30^{ns}	0.23^{ns}	0.50**	-0.39*
OD						1	0.57**	-0.11^{ns}	-0.04^{ns}	-0.09^{ns}	0.24^{ns}	0.02^{ns}	0.26^{ns}	0.12^{ns}
RQ							1	0.09^{ns}	0.09^{ns}	-0.06^{ns}	0.16^{ns}	0.08^{ns}	0.50**	-0.45*
CC								1	0.23^{ns}	0.19^{ns}	-0.09^{ns}	0.43*	0.40*	-0.26^{ns}
ACD									1	0.36*	0.47*	0.83**	0.72**	-0.69**
BOD										1	0.04^{ns}	0.60**	0.49**	-0.41*
FLA											1	0.64**	0.62**	-0.60**
CQ												1	0.89**	-0.80**
TQ													1	-0.89**
GR														1

*** and * = Correlation significant at 1% and 5% level of significance, respectively; ns=non significant; DP=drying period; PD=primary defects; SD= secondary defect; SAM= shape and make; COL= color; RQ=raw quality; CC = cup cleanness ACD=acidity; BOD=body; FLA= flavor; CQ=cup quality ; TQ=total quality; GR=grade*

5. SUMMARY AND CONCLUSION

Coffee is the most important crop in the national economy of Ethiopia and still the leading export commodity. Coffee quality is of critical importance to the coffee industry. Quality coffee is a product that has desirable clean raw and roasted appearance, attractive aroma, and good cup taste. However, it is beyond dispute that in Ethiopia the quality of coffee produced by farmers has been deteriorating form time to time. The findings of this research indicate that in respect to method of drying, drying temperature and initial moisture content of parchment the artificial drying method in combination with high drying temperature and low initial moisture content produce specialty grade 1 coffee. The result of the research shows that artificial drying method is better than sun drying method at the initial moisture content of 16% and drying temperature of 90 ^{0}C with respect to drying time.

The coffee with an initial moisture content of 16% dried earlier at drying temperature of 90^{0}C while the coffee with initial moisture content of 40% which is dried at drying temperature of 60^{0}C took longer drying period. Coffee dried with the sun took longer drying period. This indicates Initial moisture content difference varies time of drying period. Hence, drying parchment coffee at high temperature with low initial moisture content is advisable to maintain coffee quality short drying time .So drying time was influenced by the initial moisture content of the coffee and the temperature of the dryer

The total raw quality of coffee was determined by method of drying, initial moisture content and the temperature of the dryer. As a result, at moisture content of 16 % and the temperature of 90^{0}C dried with 5hr attained the maximum mean values of total raw quality attributes. On the other hand drying coffee using artificial dryer with the highest moisture content and the lowest temperature dried with 54hr this result shows that the lowest total raw quality and the longest drying period.

The synergetic effects of temperature and moisture content dictated the total cup quality. As a result, coffee dried with initial moisture content of 16% with drum temperature of

90^0C is obtained the best mean total cup quality. Moreover; the interaction among temperature and moisture content is critical in determining the total cup quality. As a result; at the initial moisture content of 16% with the drum temperature of 70^0C, 80^0C and sun drying results the highest mean total cup quality values. Coffee dried with the initial moisture content of 21% with the drum temperature of 70^0C, the initial moisture content of 26% with drum temperature of 60^0C and sun drying and 40% initial moisture content with sun drying give to statistically identical and the highest mean total cup quality. On the other hand, coffee dried with the initial moisture content of 16% with drum temperature of 60^0C and 90^0C and 21% moisture content with 60^0C, 80^0C, 90^0C and sun drying, the initial moisture content of 26 % with drum temperature of 70^0C, 80^0C and 90^0C and coffee dried with 40% moisture content with drum temperature of 60^0C, 70^0C, 80^0C and attained the lowest mean total cup quality and statistically similar.

Moreover; the total cup quality of green coffee was found to be determined by the combined effect of coffee drying methods, initial moisture content of the coffee and the drum temperature. Hence, coffee dried at the initial moisture content of 16% with drum temperature of 90^0C exhibited the highest mean total cup quality. On the other hand, coffee dried with the initial moisture content of 26% with drum temperature of 80^0C produced the lowest mean total cup quality.

The total coffee quality and grade was influenced by the interactions among, drying method, initial moisture content of the coffee and the drum temperature. As a result; coffee dried with the initial moisture content of 16% with drum temperature fixed with 90^0C induced excellent quality coffee detected to “outstanding” and received “outstanding” (90-100 points) profiled under grade 1 (under the current commercial grading). As a result; processing coffee at high temperature and low initial moisture content within short time produces outstanding grade coffee.

Hence; coffee dried at the initial moisture content of 26% with drum temperature of 80^0C induced low quality coffee (Below Specialty coffee quality < 80.00). Therefore, special attention should be given to wet processing approaches through refinement of mechanical drying methods for quality improvement of wet 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.

6. RECOMMENDATIONS

As repeatedly stated coffee production is a highly cash crop business and foreign exchange commodity. Its contribution to households' income and food security is very high. It also provides job opportunities for other peoples other than farmers. Regardless of its contribution, however, the emphasis given nationally to the sector is relatively low compared to the benefit gained from this crop. As a result of this, Processing coffee using appropriate drying method such as artificial drying method with the recommended moisture content and the appropriate temperature is needed to improve the quality of wet processed Arabica coffee. Results of the present study show that wet processed coffee dried with artificially may result good quality. Based on the research findings of this study, the following points are recommended to enhance coffee quality.

- In order to be competent in the global coffee market , it is advisable to use the following wet processing approaches:
- Drying coffee using artificial drier with the lowest percentage moisture content could produce a specialty grade coffee
- Similarly; sun drying of coffee with 16 to 40% initial moisture content levels can produce a specialty grade coffee
- So, drying coffee using artificial drier with an initial moisture content of 16% and drum temperature of 90^0C is appropriate to maintain the quality of coffee

Future Line of Work

Coffee quality can be best improved through application of appropriate artificial drying method.

- From the present findings, gaps have been identified for future research consideration:

- Identification of the processing techniques and actual differences in quality on distinctively processed coffee

- Designing and developing house hold level electrical assisted or solar assisted artificial dryer to maintain the quality of coffee

- Identifying the effect of artificial and sun drying on the fungal development in coffee during short time storage

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APENDICES

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

Source of variation	DF	Raw Coffee Quality Characteristics						
		DP	**PD**	**SD**	**SAM**	**COL**	**OD**	**TRQ**
Replication	**2**	**0.1967**	**0.7608**	**0.8727**	**0.7266**	**0.7473**	**0.9343**	**0.9411**
Temp.	**4**	**<.0001**	**0.9807**	**0.7024**	**0.3582**	**0.2649**	**0.8939**	**0.8035**
Mc	**3**	**<.0001**	**0.0034**	**0.6837**	**0.3299**	**0.2583**	**0.0985**	**0.0033**
TEMPXMC	**12**	**<.0001**	**0.4885**	**0.7146**	**0.5439**	**0.4004**	**0.4684**	**0.2366**
CV (%)	**2**	**1.19**	**13.60**	**7.15**	**5.71**	**19.90**	**10.71**	**5.53**

R=replication; T= temperature; E- temperature; (factor A)……….. Mc=moisture content; TEMPXMC= interaction between temperature and moisture content; CV=Coefficient of variance. ; DF=Degrees of freedom; DP=drying period; PD=primary defects; SD= secondary defect; SAM= shape and make; COL= color; RV=raw value;

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

R=replication; T= temperature; E- temperature; (factor A)…….. Mc=moisture content;

Source of variation	DF	Organolephtic Coffee Quality Characteristics						
		CC	**AC**	**BOD**	**FLV**	**TCV**	**TQ**	**GR**
Replication	**2**	**0.4169**	**1.0000**	**0.2885**	**0.9237**	**0.95**	**0.9381**	**0.7266**
Temp.	**4**	**0.5052**	**0.2640**	**0.3791**	**0.0205**	**0.6285**	**0.5501**	**0.1633**
Mc	**3**	**0.3251**	**<.0001**	**0.7339**	**0.039**	**0.0130**	**0.0006**	**0.0009**
TempXmc	**12**	**0.6676**	**0.0032**	**0.8737**	**0.0057**	**0.0077**	**0.0036**	**0.0112**
CV (%)	**2**	**8.35**	**9.85**	**13.47**	**12.66**	**6.51**	**4.14**	**19.09**

TEMPXMC= interaction between temperature and moisture content; CV=Coefficient of variance. ; DF=Degrees of freedom; CC = cup cleanness ACD=acidity; BOD=body; FLA= flavor; CV=cup value; TV=total value; GR=grade

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

Washed Coffee Quality Assessment

Raw value _____
Moisture content________%
Cup value_______
Retained on screen_______%
Total point_______

Raw value (40%)										Value (60%)							
Defects (20%)				Shape& make (10%)		Color (5%)		Odor 5(%)		Cup cleanness (15%)		Acidity (15 %)		Body (15%)		Flavor (15%)	
Primary (count)(10%)	Pts	Secondary (wt)(10%)	Pts	Quality	Pts	Quality	pts	Quality	pts	Quality	Pts	Intensity	Pts	Quality	pts	Quality	pts
0	10	<5%	10	V.good	10	Bluish	5	Clean	5	Clean	15	Pointed	15	Full	15	Good	15
1-4	8	<8%	8	Good	8	Grayish	4	F.clean	4	F. clean	12	M.pointed	12	M .full	12	F.Good	12
5-6	6	<10%	6	F.good	6	Greenish	3	Trace	3	1 CD	9	Medium	9	Medium	9	Averag	9
7-10	4	<12%	4	Average	4	Coated	2	Light	2	2 CD	6	Light	6	Light	6	Fair	6
11-15	2	<14%	2	Fair	2	Faded	1	Moderate	1	3 CD	3	Lacking	3	Thin	3	Commonish	3
>15	1	>14%	1	Small	1	White	0	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 IV. Raw defect type & evaluation system of SCAA and Ethiopia green coffee bean (ECX, 2009)

w defects																					
Parchment observations										SCAA primary Defects		Secondary defects observations									
Type	0	1	2	3	Type	0	1	2	3	Type	Bean grade	SCAA	0	1	2	3	Ethiopia	0	1	2	3
Even					Under washed					Full black		Partial					Foxy				
Under grade					Cracked					Full sour		Partial					Under dried				
Improper					Dull					Fungus		Floater					Over dried				
Discolored					Pods					Foreign matter		Immature					Mixed				
Nipped					Mixed fermentation					Insect damaged		Withered					Stinkers				
Fermented					Under fermentation							Shell					Faded				
Loose					Long cont. water							Slightly insect damaged					Coated				
Brownish																	Light Starved				
										Total		total									

APPENDIX FIGURE

Appendix fig 1 coffee cupping laboratory

Appendix fig 2 certified quality graders