Assessment of Postharvest Management and Effects of Harvesting Methods and Drying Structures on Unwashed Coffee (*Coffea arabica* L.) Quality in *Kercha* District, Southern Ethiopia

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Assessment of Postharvest Management and Effects of Harvesting Methods and Drying Structures on Unwashed Coffee (*Coffea arabica* L.) Quality in *Kercha* District, Southern Ethiopia

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ADVISORS' APPROVAL SHEET

(Submission Sheet I)

This is to certify that the thesis entitled:**"Assessment of Postharvest Management and Effects of Harvesting Methods and Drying Structures on Unwashed Coffee (*Coffea arabica* L.) Quality in *Kercha* District, Southern Ethiopia**" submitted in partial fulfillment of the requirements for the degree of **Master of Sciences** with specialization in **Horticulture** to graduate program of the School of **Plant and Horticultural Sciences**, College of Agriculture, and is a record of original research carried out by **Daniel Duba Bulula,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it be accepted as fulfilling the thesis requirements.

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Name of major advisor	Signature	Date
	OR	
Hussien Mohammed Beshir (PhD)	_____	_____
Name of co-advisor	Signature	Date

DEDICATION

I dedicate this thesis manuscript to my lovely Father DUBA BULULA and my lovely Mother MARTA ABABA for nursing me with affection, love and for their dedicated parent ship for the success I achieved in my life. Their ceaseless support, esteem, cares and schooling fulfilled all my desires beyond their capabilities; nursed me with fondness, shaped my life and enabled me to contribute this to the final users.

STATEMENT OF THE AUTHOR

I declare and assert that this MSc. thesis is my original work and that all sources of materials used for the thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. It has been submitted to Hawassa University in partial fulfillment of the requirements for the MSc. degree in Horticulture, and it will be deposited at the University's library and available to borrowers under the rules of the library.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CRD	Completely Randomized Design
CSA	Central Statistical Agency
CLU	Coffee Liquor Unity
DAs	Development Agents
ECTDMA	Ethiopia Coffee and Tea Development and Marketing Authority
ECX	Ethiopia Commodity Exchange
EIAR	Ethiopia Institute of Agriculture Research
FAO	Food and Agricultural Organization
GLM	General Linear Model
ICO	International Coffee Organization
KDCTDMAO	*Kercha* District Coffee and Tea Development and Marketing Authority Office
LSD	Least Significance Difference
NMA	National Meteorology Agency
OTA	Ochratoxin A
PLCTC	Primary Level Coffee Transaction Center
SAS	Software for Agricultural Sciences
SCAA	Special Coffee Association of America
SPSS	Software Package for Social Sciences
SNNPRS	Southern Nations, Nationalities and Peoples' Regional State

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Assessment of Postharvest Management and Effects of Harvesting Method and Drying Structures on Unwashed Coffee (*Coffea arabica L.*) Quality in *Kercha* District

Daniel Duba (BSc.), Gifty Abera (PhD candidate) and Hussien Mohammed Beshir (PhD)

ABSTRACT

Arabica coffee, which has 75-80% share in the world coffee production and marketing is the most important economic crop in Ethiopia. Unwashed coffee shares 71% of total coffee processed in the country. There is lack of profound assessment work to identify the specific postharvest management practices that affecting the quality of unwashed coffee in Kercha district, and effect of harvesting method and drying structures on each quality parameters of the coffee as general. The study was designed to assess the postharvest management practices, and evaluate the effects of harvesting methods and drying structures on unwashed coffee quality in 2018 production season. For the assessment, from 3 representative kebeles, 120 households were selected randomly. A total of 9 focused group discussion (role model, non-role model and women farmers) and 15 key informant interviews were employed. Survey data were analyzed by using Software Package for Social Sciences (SPSS). The experiment was conducted as a factorial combination of two harvesting methods (selective picking and stripping) and four drying structures (bare ground, cemented floor, bamboo mat bed and mesh wire bed) in Completely Randomized Design with three replications. Coffee quality analysis was done in laboratory by certified panelists' team of Ethiopia commodity exchange (ECX) enterprise following the standardized grading scale procedures. Experimental data were analyzed by using Software for Agricultural Sciences (SAS) and General Linear Model (GLM) procedures. The results showed that in the district, 50.8%, 100%, 82.5% and 33.3% of the farmers harvesting their coffee by stripping at inappropriate fruit maturity stage, packing with polyethylene sack, storing at inappropriate place and transacting at illegal market respectively. The interaction of the harvesting methods and drying structures showed significant effect ($P<0.0266$) on the primary defects, acidity and body of unwashed coffee. Similarly, the interaction effect was significantly ($P<0.0018$) affected the flavor and total cup quality of the coffee. The main effect of the harvesting methods showed significant effect ($P<0.0001$) *on the secondary defects and total raw bean quality. The main effect of the drying structures revealed significant effect ($P<0.0001$) on the odor of the beans. Both the main effects of harvesting methods and drying structures showed significant effects ($P<0.0001$) and ($P=0.0002$) on the overall coffee quality. Generally, in Kercha district, postharvest management practices of unwashed coffee are amongst the main problems that affecting the coffee quality. Selective picking with mesh wire bed, bamboo mat bed and cemented floor resulted in better quality coffee than stripping with all of these structures, and selective picking with bare ground. Therefore, there should be improvement in coffee harvesting methods, storage and transactions conditions in the district. Besides, selective picking with drying on bamboo mat bed which maintains the inherent quality of unwashed coffee is recommended for the farmers.*

Key words: *Berries, Cherries, Drying structures, Harvesting, Quality, postharvest*

1. INTRODUCTION

1.1. Back ground and Justification

Coffee is one of the most important traded commodities of the world, and still it is remained the second ranked traded commodity after fuel when compared with non-food items (Hinsene *et al.,* 2015; ICO, 2017; Seifu *et al.,* 2016). About 75-80% and 20-25% of total world coffee production and marketing comes from Arabica and Robusta coffee respectively (Mohammadsani, 2014). Hence, Arabica coffee has more than three folds of Robusta coffee shares in the international coffee production and marketing. Arabica coffee (*Coffea arabica* L.), which belongs to *Rubiaceae* family was originated in Ethiopia and well known for its superior quality (Alemu, 2015; Bote and Struik, 2011; DaMatta and Ramalho, 2006; Eira *et al.,* 2006; Netsere, 2015; Tsagaye *et al.,* 2014). The crop grows between the latitude range of $0\text{-}25^0$ both in north and south hemisphere from the equator (DaMatta and Ramalho, 2006). It grows under various agro-ecological conditions and thrives best between altitudes of 1300 and 1800 meters above sea level with annual rainfall amount ranging from 1500 to 2500 mm (Pinheiro *et al.,* 2005). It requires ideal minimum and maximum temperatures of 15^0c and 25^0C respectively (Abadiga, 2010; Seifu *et al*., 2016). It needs deep, well drained, loamy and slightly acidic soils (Seifu *et al.,* 2016).

The crop plays a vital role in the economic development of many developing countries of tropical region such as many African, Asian and Latin American countries (ICO, 2017). Currently, it is produced in about 80 developing tropical countries including Ethiopia (Amamo, 2014; Gathura, 2013; Vossen, 2005). Ethiopia, which produced and exported only Arabica coffee is the first and the fifth largest coffee producer in Africa and in the world next to Brazil,

Vietnam, Colombia and Indonesia respectively (Amamo, 2014; Hernandez *et al*., 2015). However, when taking in to account only the world Arabica coffee production, Ethiopia is the first and the second largest producer in Africa and in the world next to Brazil respectively; with only about 5% contribution to the world coffee marketing (Abu and Teddy, 2013; Amamo, 2014; Kufa, 2017).

The crop still remained the most important economic crop in Ethiopia as it has been leading the export and generating foreign currency for the country over the many years (Abadiga, 2010; Hernandez *et al*., 2017; Hinsene *et al.,* 2015). Nevertheless, its share in the exports of the country has been declining from time to time due to the increasing or diversifying exports such as gold, flowers, fruits and vegetable, textile, meat, leather and leather products, etc. Also it is still left the most important agricultural commodity for the country in generating foreign currency. It has 25–35% of gross domestic product (GDP) of the country (Amamo, 2014; Mohammadsani, 2017; seifu et *al*., 2016). Now a days about 25% of the national human population of the country is depending directly or indirectly on coffee production, processing and trade for their livelihood (Seifu *et al.*, 2016). About 90% of total coffee produced in the country comes from the small-scale farmers who have limited access to coffee postharvest management technologies (Hernandez *et al*., 2015; Kufa, 2017). In Ethiopia, the crop has not only economical values but also it is well known for its social, cultural and environmental values (Abu and Teddy, 2013; Teshale, 2017). About half of the coffee produced in the country is consumed domestically in different forms, and let the country not only the largest coffee producer but also the largest coffee consumer in Africa continent (Amamo, 2014; Mohammadsani, 2017; Seifu *et al.,* 2016; Tsagaye *et al.,* 2014). The coffee bean is hygroscopic by its nature; thus, care should be taken to control its quality (Seifu *et al*., 2016; Tsagaye *et al.,* 2014).The quality of the beans can easily be

affected by many factors such as varieties, agro-ecological conditions, agronomic practices, post-harvest management and handling practices, diseases and insect pest, and 40% of its quality is determined by these factors (Alemu, 2015; Cheng *et al.,* 2016; DaMatta *et al.,* 2008; DaMatta and Ramalho, 2006; Mohammadsani, 2014, 2017**)**.

There are two types of common coffee processing methods in many coffee producing countries including Ethiopia; namely wet processing and dry processing methods (Seifu *et al.,* 2016). Currently, about 71% of total coffee processed in Ethiopia is processed by dry processing (unwashed coffee) with only 29% share of wet processing (Mohammadsani, 2017). Relatively, unwashed coffee has lower quality than washed coffee due to higher acidity left over the beans of unwashed coffee which resulted from different factors like harvesting methods and drying conditions (Abadiga, 2010). Coffee harvesting methods and drying structures are among the major factors of postharvest that affect coffee quality, and vary from place to place in the country (Mohammadsani, 2017; Garo *et al*., 2016). There are different manual methods of coffee harvesting such as selective picking, stripping, collecting from the ground, etc. that practiced by coffee producers (Seifu *et al.,* 2016). Also farmers and coffee processors use different coffee drying structures such as bare ground, cemented floor, bamboo mat bed, mesh wire bed, etc., which varies from place to place in the country (Mohammadsani, 2014, 2017). Usually, farmers harvest and dry immature, green mature, overripe black and red ripe coffee fruits together for unwashed coffee production. These mixtures of the fruits with different growth stage lead to the poor quality of unwashed coffee compared to the washed coffee in which almost red ripe cherries are depulped, fermented and washed (Mohammadsani, 2017). Hence, there is no doubt that postharvest management practices affect the quality of unwashed coffee. In order to improve the economic benefits of coffee producers especially of small-scale farmers, the knowledge of

post harvest management practices and coffee quality status in different coffee producing areas of the country is important. *Kercha* district is one of the largest coffee producing districts of Ethiopia both in total area covered with coffee and total volume of coffee produced (ECTDMAO, 2017). Although the importance of coffee and its quality sensitivity to different factors like postharvest management practices, there is lack of profound assessment works to identify the specific postharvest management practices that affecting the quality of unwashed coffee in the district. On the other hand, previous studies reported only the effects of other factors on the total raw and total cup quality thereby on the overall quality of coffee without addressing the effects of harvesting methods and drying structures on each quality parameters of unwashed coffee like odor, flavor, acidity, body, etc. Therefore, assessment of the postharvest management practices including harvesting methods and drying structures to evaluate the effects of these on the quality of unwashed Arabica coffee is imperative. In line with this, current study was investigated the postharvest management practices of unwashed Arabica coffee in *Kercha* district, and evaluated the effects of harvesting methods and drying structures on its quality.

1.2. Objectives

1.2.1. General Objective

- To assess postharvest management practices, and evaluate the effects of harvesting methods and drying structures on the quality of unwashed Arabica coffee in *Kercha* district

1.2.2. Specific Objectives

- To assess postharvest management practices of unwashed Arabica coffee in *Kercha* district
- To evaluate the effects of harvesting methods and drying structures on the quality of unwashed Arabica coffee

2. LITERATURE REVIEW

2.1. Harvest and Postharvest Management Practices Affecting Coffee Quality

2.1.1. Coffee Harvesting Methods

Many studies elucidated the importance of harvesting methods in determining and affecting the quality of coffee. It was reported that coffee can be harvested by mechanical and manual methods in which the later is more common and recommended in the world coffee producing countries (Gathura, 2013). Each of these methods has its own advantages and disadvantages in terms of speed of harvesting, cost of harvesting labors or machines, and final quality of coffee (Seifu *et al*. 2016). Daniels (2009) pointed out that during coffee harvest most practices are focused on quantity and speed, not quality.

Garo *et al*. (2016) studied harvest and postharvest factors affecting quality of Arabica coffee in southern Ethiopia, and explicated that traditional hand picking and husbandry labor, as opposed to mechanical harvest produced best quality green coffee by decreasing the percentage of defects in coffee batches. Their finding depicted that there were three different manual harvesting methods in the study areas namely selective picking, stripping on the ground and collecting in bulk, and collecting from the ground the fruit which was dropped from the tree.

Similarly, Abadiga (2010) pointed out that ‘collecting the dropped cherries from the ground’’ as the third method of coffee harvesting in addition to selective picking and stripping methods. On the other hand, it was reported that coffee is harvested manually by stripping method and selective picking, and more than half percent (55%) of the farmers in east Ethiopia harvested coffee by stripping method (Mohammedsani, 2014).

This is not similar to the result of the study done in southern Ethiopia particularly in Gamo Gofa zone where more than a half percent (51.3%) of the farmers used selective picking (Garo *et al.,* 2016). According to Mohammedsani (2017) coffee quality was significantly affected by stripping method. Naturally, since all coffee fruits do not ripe at the same time, red ripe cherry harvesting by selectively picking to produce high quality product requires many harvesting cycles, long time of harvesting span and huge labor forces. As opposed to selective picking, stripping method is much faster and saves much more time and labor. Despite of many cycles of coffee harvesting during the harvesting season, the previous studies did not addressed the exact cycles in which coffee could be harvested when selective picking method is used.

2.1.2. Coffee Fruit Maturity Stage during Harvest

Coffee fruit maturity stage found to impose a momentous effect on the overall quality of coffee not only solely on its raw or cup quality (Seifu *et al.*, 2016). Coffee cherry harvesting which is a crucial step may involve separating fruits at different maturation stages from the mother tree (Poltronieri and Rossi, 2016). Under ripe or overripe cherries seriously affect the taste of the final product. Abadiga (2010) pointed out the strong relationships between coffee fruit maturity stage and coffee quality that immature fruits results in color defects (grayish or dark grey) and uneven roast of beans.

Coffee quality once affected and deteriorated, it cannot be improved; and hence, quality control is necessarily important (Amamo, 2014). In order to control coffee beverage quality, aroma, thickness of the brew, taste and flavor as well as acidity in cup analysis, it should be harvested at red ripe stage. Therefore, coffee harvesting is favorable when the cherries attained full red rip stage.

2.1.3. Coffee Harvesting Materials

The containers with in which cherries to be harvested were reported to affect coffee quality. Cherries and beans are notoriously hygroscopic which means sensitive in attracting different smells and moisture (Seifu*et al.*, 2016). It was explicated frequently by many researchers that harvesting containers should be free from chemicals and any other foreign materials which affect the final quality of coffee.

In Ethiopia, different harvesting materials which are economically and technically feasible and affordable at small-scale farmers are used in many coffee producing areas (Abadiga, 2010). These materials include basket made up of bamboo, local wooden container, polyethylene sack, jute sack, etc. According to Garo *et al.* (2016), in Gamo Gofa zone of SNNPRS of Ethiopia, around 95.7% of coffee farmers used appropriate harvesting materials; that is local containers (bamboo and wooden made basket) which were reported to have no contact with other chemicals. Hence, the farmers in the area avoided using plastics/polyethylene sacks for coffee harvesting as it has an opportunity to contaminate coffee quality especially when the container is used for transporting grains and/or chemical fertilizers.

2.1.4. Coffee Drying Structures

After harvest, the drying structures reported to exert the noteworthy effect on and determine the quality of coffee (Abadiga, 2010). Drying structures used to support coffee cherry drying to appropriate moisture content. As cherries layered over the surfaces of drying structures which is exposed to the heat sources usually solar energy, the cherries can be dried to appropriate moisture level given that available drying power supply. However, the structures on which the

cherries dried reported to exert significant effect on the quality of coffee (Mohammedsani, 2017; Garo *et al*., 2016). Coffee stake holders use different structures to dry coffee cherries and beans including bare ground, cemented floor, bamboo mat bed, mesh wire bed, etc.. Many researchers clarified that there is significant effect of these structures in determining the final quality of coffee.

Mohammedsani (2017) reported that the use of drying structures including concrete, plastic sheet, bamboo mat bed and raised mesh wire bed can be encouraged in maintaining and improving inherent quality of Arabica coffee. Similarly, Garo *et al*. (2016) reported that in Gamo Gofa zone of SNNPRS, coffee cherries which had contact with ground (soil) resulted in earthy flavor in the final cup taste and also the raw coffee quality was less attractive.

Thus, inappropriate drying structures can be considered as one of the main problems contributing to low coffee quality in southern Ethiopia particularly in Gamo Gofa area. It was elucidated that ground leveled with mud and cow dung were highly used at farmers' level whereas cemented floor and raised bed with mesh wires were used by private coffee processors.

2.1.5. Coffee Drying and Sorting

While drying coffee cherries and/or beans, the important related activities those affect coffee quality like sorting and stirring can be performed simultaneously. Coffee beans moisture content is one of the most remarkable postharvest factors that determine both raw and organoleptic quality of coffee (Seifu *et al.,* 2016). It was elucidated frequently by scholars that coffee beans should be dried from more than 50% moisture level during harvesting to 10-12% moisture content regardless of the applied coffee processing method (Daniel, 2009; Eira *et al.,* 2006).

Drying coffee cherries and beans to appropriate moisture level is imperative to prevent fungal development that affects not only raw quality attributes but also organoleptic quality parameters (Poltronieri and Rossi, 2016). Poltronieri and Rossi (2016) suggested that coffee cherry drying is identified as one of the steps during which ochratoxinA (OTA), mycotoxin produced by fungi is formed under humid tropical conditions. The moisture content of green coffee beans should be maintained between 11-12% to prevent mold development (Garo *et al*.2016; Seifu *et al*., 2016).

Accordingly, the moisture content in the range helped the beans to preserve the inherent quality; whereas above 12% moisture level facilitates mold development that affect both raw and organoleptic coffee quality. The bean also loses flavor and weight at 8% moisture content that affecting the way of coffee bean roast and weight (FAO, 2005; Seifu *et al*., 2016). Therefore, dryness of coffee to appropriate moisture level is important not only to prevent fungal growth, but also maximizes the value because coffee cherries and beans are sold on a weight basis.Daniel (2009) and Garo *et al*. (2016) explained that generally there are two methods of testing the degree of moisture of coffee beans; these are digital and dental methods.

The dental method involves peeling the parchment of an individual bean and biting it with incisors. If it is easily dented or even cut by the bite, it is not dry. If a hard bites or hardly dents the bean, it is dry. The dental method is subjective and non-accurate method. On the other hand, the digital method relies on a digital coffee moisture meter (tester); when correctly calibrated, it is the best method to determine moisture content of coffee. Although the above methods are a common to test moisture level of coffee beans, others traditional methods like sound of cherries or beans, were reported to check whether or not the cherries or beans dried, without determining the exact proper moisture level of coffee beans.

Garo *et al*. (2016) have clarified that in southern Ethiopia, at farmers' level, almost the exact moisture level of coffee beans had not been determined, and that resulted in mold development. It was pointed out that 51.3%, 32.5% and 13.1% of the farmers used cherries sound, crushing the bean with their teeth, and stored their coffee without considering moisture level to check dryness of beans respectively.

Sorting is one of the most imperative postharvest activities in determining the final quality of coffee, and it takes a significant amount of time (Daniels, 2009; Seifu et *al.*, 2016). According to Daniel (2009), the considerable time investment for sorting can be avoided in two ways. First, harvesting only red ripe cherries selectively that can be depulped by machine, and leaving the unripe berries for the later harvest. He described that harvesting in that way is significantly slower. As described by the researcher, the second way avoiding sorting is simply storing all the harvested fruits to allow the pulp to rot, and allow coffee to dry over the courses of several months. Therefore, the amounts of defects in the cherries or beans have significant effect on the final quality of coffee.

2.1.6. Coffee Packing and Storage

It was reported that packaging and storage place and duration are the other most important and essential factors required for maintaining and improving coffee quality apart from harvesting method and drying structures (Mohammedsani, 2014). Coffee bean storage conditions and storage durations were found to be the important storage factors that affect raw and liquor quality of coffee (Seifu *et al*., 2016). Storage is described as an important step, since the dried coffee can easily absorb flavors or moisture that degrades the quality (Abadiga, 2010; Daniel, 2009). Storage conditions including storage room facilities such as aeration for free air circulation; free

from chemical and foreign materials contamination; avoid smoke and fuels sources; avoid direct contact of the coffee beans or cherries containing bags with the ground as well as with the wall of storage room; etc. affect coffee quality (Abadiga,2010). Therefore, having dried to proper moisture level, coffee cherries and/or beans should be packed with woven jute sack and stored in ventilated cool dry area far away from such potential contaminants (Seifu *et al*., 2016; Garo *et al*., 2016; Tsagaye *et al.*, 2014).

According to Abadiga (2010) storage durations significantly affect the quality of coffee even if other factors are maintained at optimal levels. It was reported that even under adequate or optimal storage conditions, coffee beans deteriorate with age and the phenomena would be accelerated when the environment is hot and/or humid, and the bean takes off-flavor due to the oxidation of its own fats (Tsagaye *et al.*, 2014). Therefore, if longer storage is sought, it is better to store at a temperature blow 20 °C and 65% relative humidity (Garo *et al.*, 2016).

2.1.7. Coffee Processing Methods

Many several studies clarified that coffee processing method is one of the most important postharvest factors that determines and affects coffee quality (Abadiga, 2010; Mohammedsani, 2017; Seifu et *al*., 2016; Tsagaye *et al.,* 2014). The studies indicated also wet processing and dry processing methods are the two common coffee processing methods in the world coffee producing countries including Ethiopia. Usually, wet processing which is used to produce green beans of washed coffee results in the higher quality coffee than dry processing that produces unwashed coffee beans (Seifu *et al*., 2016). Poltronieri and Rossi (2016) explained that comparing to wet processing, dry processing method is technically simpler, environmental friendly and economically lowers capital investment. Dry processing method used to process natural or sun dried coffee cherries to produce coffee beans. The coffee produced in this way is

known as unwashed coffee or natural coffee (Seifu *et al.*, 2016). In unwashed coffee processing, cherries after harvest allowed to dry in sun with intact pulp and mucilage for several weeks to months depending on the environmental conditions (Poltronieri and Rossi, 2016). Since no layer and mucilage are removed from the cherries, fermentation can occur and the final product develops characteristics fruity and cherry flavor (Daniel, 2009).

Although dry processing is easier way to transform coffee cherries into beans, it was reported that it is more difficult way than wet process to produce high quality coffee. It relies completely on solar energy and use of flat surfaces where cherries are layered to dry. The drying structures or flat surface on which cherries layered to be dried affects the inherent and overall coffee quality (Mohammedsani, 2017). According to Garo et *al.* (2016) the negative effect on the quality of dry processed Arabica coffee was due to the different faults those were committed by farmers or processors during harvest and postharvest like strip harvesting and drying on bare ground.

Dry processing is a common method for Arabica coffee processing in many coffee producing countries of the world like Ethiopia. Arabica coffee processed by this method represented 71%, 80%, and 60% of Ethiopia, Yemen and Brazil coffee respectively (Mohammedsani, 2017; Daniel, 2009; Hernandez *et al*., 2015; Poltronieri and Rossi, 2016). Mohammedsani (2017) reported that Arabica coffee entirely processed by dry processing method in eastern Ethiopia, particularly in Hararghe which can be manually by using pestle and mortar at farmers' level or mechanically by machine at the processors' level. The author observed and reported that high value of 32.33%, 30.33% and 29.7 2% scores for total raw quality of washed, unwashed and semi-washed coffee respectively.

2.1.8. Coffee Transportation and Marketing

The truck for coffee transportation should be free from chemicals like fertilizer, pesticides, cosmetics, etc., and avoid transportation of any other materials like grain, oil crop, pulse, etc. together with coffee (Seifu *et al*., 2016). Over loading should be avoided; once the loading at optimum level with proper manner is completed, the load should be covered and sealed with strong plastic to prevent the potential contaminant and absorption of moisture, dust particle, smoke, etc. During loading and unloading of coffee bean bags, the bags should be kept away from the smoke released from the trucks' fuel combustion to prevent the contamination.

Similarly, care should be taken during transportation as the truck loaded with coffee beans travels across abroad. There could be a chance of contamination due to variations in climate conditions like too high relative humidity, high temperature, etc.; polluted environment such as dusty and released industrial and fuel combustion. Coffee beans can easily attract and absorb moisture and dusty particles from the surrounding environment as it is hygroscopic by its nature. These potential contaminants from the environment significantly affect the final quality of beans (Seifu *et al*., 2016; Poltronieri and Rossi, 2016).

Amamo (2014) has given explanation on coffee market and marketing as the place and activity that exercised in determining coffee quality. Accordingly, in Ethiopia there are three coffee transaction centers vz.1) Primary Level Coffee Transaction Centers (PLCTC): is a place where coffee farmers and suppliers transact coffee. These are located near to the coffee farms.

2) Ethiopian Commodity Exchange (ECX): The secondary level where coffee transact in Ethiopia. Currently, ECX coffee warehouses are located at 9 different parts of the country. The centers are found in Dire Dawa, Hawassa, Dilla, Sodo, Bonga, jimmah, Bedele, Gimbi and Bule Hora. 3) International coffee market: The third level where Ethiopian coffee transaction takes place. In that level, the exporters sell coffee to importers. In Ethiopia, only the citizens export coffee beans.

Mohammedsani (2014) has pointed out that coffee price in the international market has always been being fluctuating and affected mainly by overproduction. However, there is also a persistent demand for the quality coffee in the world. Accordingly, coffee quality is the most important factor that determines the desirability and market value of coffee in the world coffee marketing. In Ethiopia, the effect of marketing on coffee quality is determined through the respective coffee growing origins.

According to the country's rule and regulation, coffee sold to commercial market should be traceable to its growing origin in order to regulate the inherent coffee quality. The country exported its coffee on the basis of its respective origin to ensure inherent distinct coffee quality according to its preference in the international market. Smuggling of coffee to other areas affect the coffee quality of specific origin as it adulterated the coffee with which it was mixed (Seifu *et al.,* 2016; and Garo *et al.,* 2016).

2.2. Coffee Quality and Its Evaluation

Coffee quality is described in terms of combination of organoleptic or biochemical composition of variety, growing origin or agro-ecological conditions, agronomic practices and postharvest management practices (Bote and Struik, 2011; Seifu *et al*., 2016). Each of these factors affects the overall coffee quality not only when combined together but also exclusively (Abadiga, 2010; DaMatta et *al.*, 2008; Garo *et al*., 2016; Tsagaye *et al.,* 2014).

Coffee quality may seem subjective since it is related to how it tastes and smells, and personal preferences and sensitivities varied widely. However, there is an increasing body of research that treated coffee quality as a quantifiable characteristic (Abadiga, 2010; Mohammedsani, 2017; Daniel, 2009). Accordingly, well experienced, qualified skilled professional panelists' team evaluates both raw quality attributes and the organoleptic characteristics of coffee and scores the value for each quality parameters (Mohammedsani, 2017).

Poltronieri and Rossi (2016) explained different systems of coffee quality scoring in different coffee exporting and importing countries although the description of the quality has no difference. These classified as numerical scoring and categorical scoring. They pointed out that Specialty Coffee Association of America (SCAA) used the numerical score which goes only from six up to ten rating. On the other hand, Brazilian Scoring System (BSS) used categories such as strictly soft (very smooth flavor, slightly sweet, low acidity), hard (astringent flavor, rough taste, lacks sweetness) and rio zona (intolerable taste and smell). In America, SCAA only deals with high quality coffee which will presumably never scored below six score whereas in Ethiopia, ECX dealt both with high quality and poor quality coffee that has a range of one up to nine grading score (Mohammedsani, 2017; Daniel, 2009).

According to the information extracted from the respective office, there are six different successive points where coffee quality can be checked as it goes from the specific producing farm to the export market level. The quality can be checked consecutively at farm gate, primary markets and primary processing during the primary level quality analysis by selective picking, red ripe and /or dry cherries marketing and sorting respectively. Up on the arrival at ECX and certification centers that is at export level, secondary quality analysis undertaken by moisture content evaluation, defects assessment, overall quality evaluation and certification. Coffee quality evaluation involves two successive stages to determine the overall coffee quality namely: raw beans evaluation and cup quality evaluation (Seifu et *al.*, 2016)

2.2.1. Coffee Raw Bean Quality Evaluation

In raw test, the physical appearance and quality attributes such as odor, color, shape and size of beans are used to evaluate the quality of coffee (Bote and Struik, 2011;Hinsene *et al*.,2015; Mischer,2001;Seifu *et al.*,2016; Tsagaye *et al.*,2014). In addition, Daniel (2009) has explained that the number of visually defective beans including black beans, mottled beans, broken beans, and crystallized beans plays a significant role in determining how the coffee could be graded; each of these indicates a specific problem with the processing that will also be noticeable in the next step, the cupping of the samples.

Mohammedsani (2017) explained that coffee raw beans quality evaluation represents 40% of overall coffee quality estimation, and can be affected during postharvest management and primary processing activities like depulping/hulling, drying, storage, etc. Therefore, postharvest management practices and primary processing activities are important in controlling or affecting the overall coffee quality (Mohammedsani, 2017; Seifu et *al.*, 2016; Garo *et al*., 2016).

2.2.2. Coffee Cup Quality Evaluation

Coffee cup quality referred to brew or liquor quality of coffee which resulted from change in biochemical composition of coffee beans (Tsagaye *et al.,* 2014). In order to evaluate coffee cup quality, the bean passed through secondary processing activities such as roasting, grinding, brewing and cupping (Seifu *et al*., 2016).

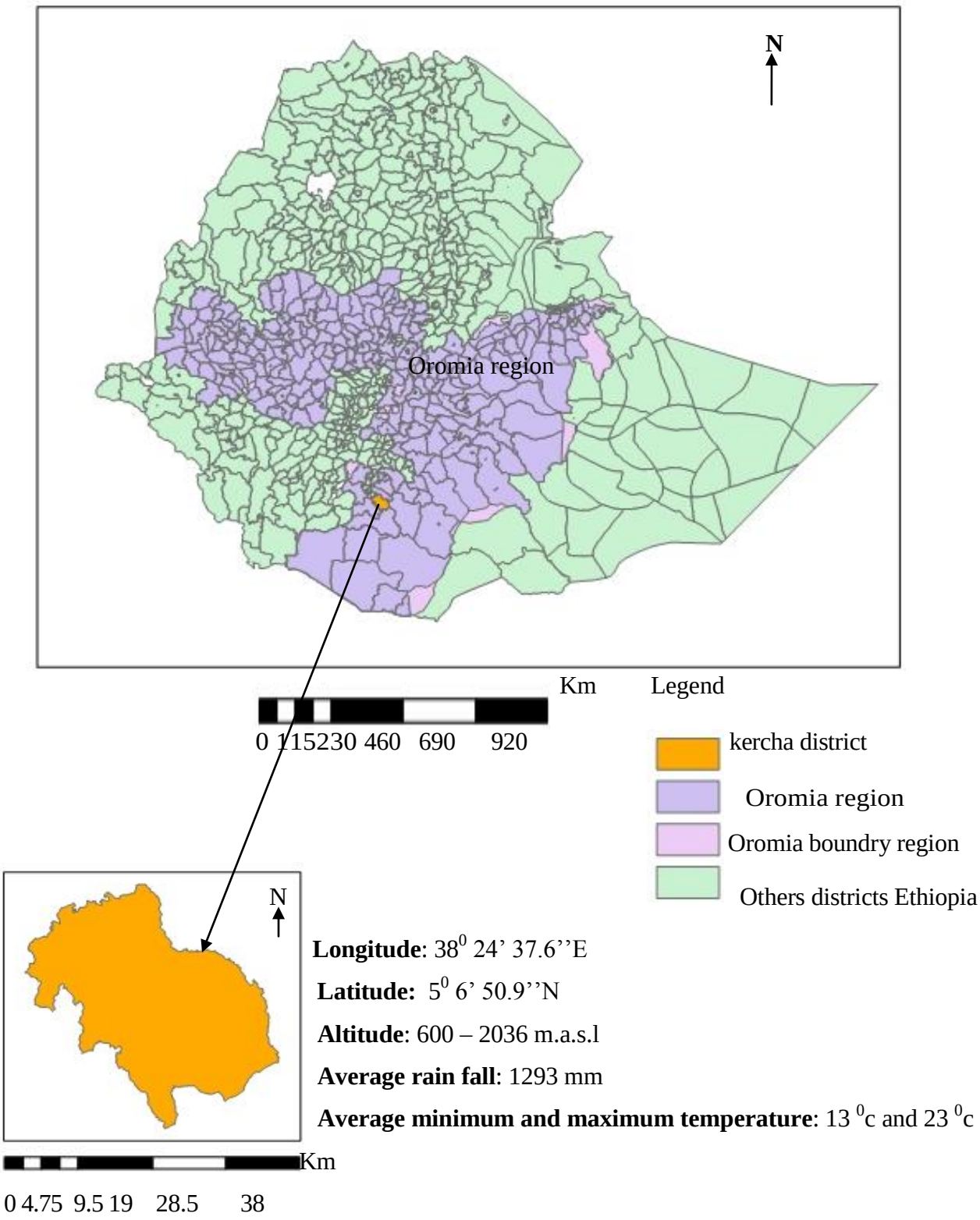
These processes enforce the beans releasing different chemical compositions those are responsible for coffee cup quality parameters such as flavor, body, acidity and cleanness of cup (Mohammedsani, 2017). Cup quality evaluation is also known as organoleptic quality evaluation and it represents 60% of overall coffee quality evaluation (Seifu*et al*., 2016; Kebede, 2012; Tsagaye *et al.,* 2014).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in *Kercha* district of West *Guji* Zone, which is the largest district both in volume and area coverage in coffee production in the zone; where about 28,422 hectares of the land covered with coffee, and 16,000 tons of its annual production comes from (KCTDMAO, 2017). The district is situated at 38^0 24’ 37.6’’E and 5^0 6’ 50.9’’N longitude and latitude respectively and far away 471 km to the south of Addis Ababa (Figure 1). It is bordered to Hambela-wamena to north, Birbisa-kojowa to east, Melka-soda to south and Bule-hora districts to the west in the zone. The area receives 1293 mm annual rainfall with the mean minimum and maximum temperature of 13°C and 23°C respectively, and has altitude range of 600-2036 m.a.s.l. The information regarding to the climatic conditions acquired from National Meteorology Agency.

The 2007 national census reported a total population of the district to be 227,362 of which 113,882 were men and 113,480 were women. According to the central statistics agency (CSA) report, about 96% of the district population was rural dwellers whereas 4% was urban dwellers. Coffee is the basic livelihood for the rural peoples being the most important source of income and *enset* is the most important staple food for the community living in *Kercha* district. Also the rural peoples practice production of some cereal crops like maize, *teff,* etc, and some livestock rearing besides coffee and *ensent* production.



Longitude: 38^0 24’ 37.6’’E

Latitude: 5^0 6’ 50.9’’N

Altitude: 600 – 2036 m.a.s.l

Average rain fall: 1293 mm

Average minimum and maximum temperature: 13 ^{0}c and 23 ^{0}c

Figure 1 Illustration of the location of the study area

3.2. Assessment of Postharvest Management Practices of Unwashed Coffee in *Kercha* District

3.2.1. Sampling Techniques and Sample Size Determination

To decide on the sample size, information on the total number of coffee producing *kebeles* and farmers in each *kebele* of the district was collected from '*Kercha* District Coffee and Tea Development and Marketing Authority Office' (KDCTDMAO). The office already stratified (categorized) purposively coffee producing *kebeles* as major, medium and minor producers based on the average amount of the coffee produced (500 Kg clean coffee beans per hectar). By selecting one *kebele* from each category, totally three representative *kebeles* were selected from each category randomly out of the total 23 coffee producing *kebeles* of the district.

From the selected *kebeles,* the sample size for the study was determined using the formula adopted by Yamane Taro (1967). The formula was given as follows

$$n= N/1+N (e)^2 \quad \text{.....Equation 1}$$

Where n=sample size

N= total size of population

e= sampling error

The formula was used assuming the population under study is homogenous in character and the marginal error of the study is 8% with 92% confidence interval. The total of 120 households was considered for the study.

3.2.2. Qualitative Data Collection and Analysis

In *kercha* district, the data on the postharvest management practices of unwashed coffee including: harvesting methods, harvesting materials, fruit maturity stage during harvest, drying structures, processing methods, sorting, storage conditions, storage durations, marketing and transportation were collected from the key respondents. Administered questionnaires, focused group discussions and key informants interview were used as the instruments to collect the data.

Questionnaires were prepared and administered randomly to the selected number of households (120). The respective district already classified the farmers in each *kebeles* as role models and non-role models based on their awareness and accessibility for the agriculture extensions. From each selected *kebele*, three focused groups' discussion including: role model farmers, non-role model farmers and women group, each comprising five members was administered. A total of nine focused groups' discussions which encompassed a total of forty five members were prepared to cross-check the data collected through the questionnaires.

Other stake holders such as unwashed coffee processors, extension workers like Development Agents (DAs), district level officials and Ethiopia commodity exchange (ECX) enterprise officials were interviewed. The primary quality analysis of coffee at the district level was assessed by interviewing the 'coffee quality control and marketing expert' who is responsible to dispatch the coffee for transportation to the next marketing center where secondary quality analysis will be implemented. Similarly, the secondary coffee quality analysis at secondary coffee marketing center which is ECX enterprise was assessed by interviewing the respective experts of the enterprise. Finally, all of the qualitative data were subjected to Software Package for Social Sciences (SPSS *version* 20) and analyzed.

3.3. Evaluation of the Effects of Harvesting Methods and Drying Structures on Unwashed Coffee Quality

3.3.1. Treatments and Experimental Design

The experiment was conducted using eight treatment combinations consisting of two coffee harvesting methods (Strip harvesting and Selective picking) and four drying structures (bare ground, cemented floor, bamboo mat bed and mesh wire bed). The treatment combinations of the two harvesting methods and four coffee drying structures are presented in (Table 1). The experimental design was Completely Randomized Design (CRD) with three replications.

Table 1 Treatment combinations and treatment codes for the study

S/No.	Treatment code	Treatment combinations	Remark
1	T1	Strip harvesting with bare ground	T1= Treatment one
2	T2	Selective picking with bare ground	T2= treatment two
3	T3	Selective picking with bamboo mat bed	T3= treatment three
4	T4	Strip harvesting with bamboo mat bed	T4= treatment four
5	T5	Strip harvesting with mesh wire bed	T5= treatment five
6	T6	Selective picking with mesh wire bed	T6= treatment six
7	T7	Selective picking with cemented floor	T7= treatment seven
8	T8	Strip harvesting with cemented floor	T8= treatment eight

3.3.2. Experimental Procedures

Primarily four different coffee cherries drying structures namely bare ground, cemented floor, mesh wire bed and bamboo mat bed each has six meter length and one meter width were prepared. Each drying structure was then partitioned into 1 m^2 area to ensure the three replications for the two harvesting methods. Thus, a total area of 24 m^2 was prepared, and each area of 1 m^2 was labeled with the treatment code and made ready to receive the coffee cherries for drying. Each of the structures was prepared by considering in the manner that allows it to receive uniform sun energy used for drying the coffee fruits. Thus, any shade during the day of drying was avoided from the drying structures.

As determined by the district CTDMAO, coffee cherries were collected from the well managed coffee farm which situated at medium altitude (1550 m.a.s.l.) and owned by the role model farmers. To get 24 Kg dried coffee beans which was required for the experiment, a total of 120 Kg of fresh cherries were collected into clean jute sack from the healthy mother trees of '74165' variety of Arabica coffee. That means half amount (60 Kg) was harvested by strip harvesting and another half (60 Kg) was by selective picking.

Coffee cherries harvested by each method (strip harvesting or selective picking) were sun dried on the four drying structures prepared separately at the outdoor. String balance was used to determine the amount of the cherries used per plot. Then, 5 kg of fresh cherries m^{-2} was layered uniformly, and stirred daily to ensure uniform drying. By using grain moisture tester, the moisture content of the cherries was frequently checked by taking the recommended amount of 750 g sample from each treatment replications.

Once the cherry moisture content declined to the required level (11.5%) from more than 50% during harvesting, the husk was removed by using traditional mortar and pestle thereby winnowed and cleaned to separate the husks from the beans (Appendix Illustration 1). Then, a total of 24 samples (the replicated treatment combinations) each weight 1000 g of the coffee beans were prepared and packed in a plastic film bag for the further secondary quality analysis of the coffee. Secondary coffee quality analysis was done in laboratory following the current standardized procedures for unwashed coffee quality evaluation set by ECX enterprise (Appendix Table 1).

The certified international coffee quality panelists' team of the enterprise which has five members evaluated the coffee quality at Hawassa branch laboratory. Accordingly, for the overall quality analysis, a total of 350 g of raw bean was taken from each sample by using sensitive balance; out of this 250 g and 100 g was used for raw and cup quality evaluations respectively. To check the uniformity of the size of the beans and their moisture contents, screen sieve 14% (the amount of the beans percolated or passed down through the screen should be less than 14 percent) and grain moisture meter were used respectively. This is to ensure uniform roasting of the beans.

For the raw coffee bean physical quality evaluation, the numbers of primary defects in the beans (full black beans, full sour beans, fungus developed beans, severely insect damaged beans, foreign materials, pods/ husk) were counted. The amount of secondary defects (immature beans, withered beans, starved beans, partially broken beans, partially sour beans, slightly insect damaged beans, shell and soiled beans) was weighted, and its percentage ratio was calculated by dividing the weight of the secondary defects to the previous sample weight (350 g) beans. Odor of the beans was evaluated by smelling the raw beans filled in to a sample tray.

To evaluate the organoleptic quality attributes including acidity, body, cup cleanness and flavor of the coffee, 100 g coffee beans was medium-roasted in the roasting machine at 160 ^{0}c for 10 minutes. Speer cylinder was used to add the beans into the roasting machine. For each five clean cups which are going to be tasted, 13.75 g of the roasted bean was medium-ground by using grinding machine and added in to each cups. The coffee was then brewed by pouring boiled water (94 ^{0}c) from kettle to the full capacity of the cups containing the ground coffee. For each cup containing the ground coffee, 250 ml of boiled water was added from the kettle.

The cups containing the brew were kept undisturbed on table for 4 minutes, and then, the brew was skimmed. The skim was carefully removed from the top layer of the brew using spoons, and the brew was waited again for 10 minutes until its temperature dropped to 65^{0}c (palatable temperature for cupping). The skimming spoon was cleaned after every skims by rinsing within clean boiled water in the cup that was kept alongside with those cups to be tasted (Appendix Illustration 1).

Each members of the panelists' team tasted each cup by using spoon and spittoon, and thereby immediately recorded the value they gave for each cup on their note book. The values recorded by all members then averaged for final decision of the cup quality. During cupping, there was no information share among the cuppers about the quality of the coffee under evaluation. Hence, the evaluation was blind type, and subjective among the cuppers yet in line with ECX (2018) standardized grading scale procedures for unwashed coffee quality evaluation.

3.3.3. Experimental Data Collection and Analysis

In order to evaluate the quality of unwashed coffee, the values for the standardized quality parameters including: odor, primary defects, secondary defects, acidity, body, cup cleanness and flavor of the coffee were collected. The evaluation is based on the standardized grading scale of the current ECX for unwashed coffee quality evaluation (Appendix Table 1). The grading scale for the odor ranges from 0 up to 10 score, while that of each of the other parameters of both raw and cup quality ranges from 0 up to 15 score. High score values for these quality parameters show better quality whereas the low values indicates worse quality.

The total raw coffee beans quality (out of 40%) and the total coffee cup quality (out of 60%) values were added and thereby the points for the overall coffee quality were computed out of 100% for each treatment. Consequently, based on the values obtained for the overall coffee quality, coffee grade and its quality profile description were identified. Finally, all of the recorded values of each quality parameter of the treatments were analyzed by using Software for Agriculture Science (SAS version 9.0).

4. RESULTS AND DISCUSSIONS

4.1. Coffee Harvesting Practices

4.1.1. Coffee Harvesting Methods

In west *Guji* zone, particularly in *Kercha* district, coffee is harvested by manual method and no mechanical harvesting method is applied in the area. Basically, there are two types of manual coffee harvesting methods in the district; namely selective picking and stripping. Similarly, selective picking and stripping were the two methods of coffee harvesting that was reported in West Hararghe zone (Ameyu, 2014). However, in addition to selective picking and stripping methods, Abadiga (2010) and Garo *et al.* (2016) reported that farmers also collect the dropped cherries from the ground, and regarded this as the third method of coffee harvesting.

Indeed, the two harvesting methods (selective picking and stripping) are completely different; in *Kercha* district, during the harvesting season, there is a use of combination of the two harvesting methods at different time interval. In that case, selective picking precedes strip harvesting and only at the last cycle of harvesting, coffee is harvested by stripping method. In selective picking method, coffee harvested in many cycles until all red ripe cherries are totally finished from the tree; whereas in stripping method, fruits at different maturity stage stripped together only once leaving no berries and cherries on the tree (Appendix Illustration 2). According to the survey result, during harvesting season, 82.5% of the households (HHs) harvest their coffee by the combination method; whereas only 7.5% and 10% of them harvest their coffee only by stripping and solely by selective picking method respectively (Table 2). The previous findings reported that 48% and 55% of the coffee farmers in southern and eastern part of Ethiopia respectively, harvests their coffee only by stripping method (Garo *et.al*, 2016; Mohammadsani, 2014).

The preference of harvesting methods, and cycles depend on the intended coffee processing methods along with other factors like coffee quality, quantity, harvesting speed, harvesting cost, etc. According to the information obtained from the district 'coffee and tea development and marketing authority office', currently there is 45% and 55% of coffee processing machines for both unwashed and washed coffee processing respectively in the district. Therefore, the availability of both types of coffee processing methods throughout the district encourages the farmers to use both types of the harvesting methods.

Usually, red ripe fresh cherries are preferably used for wet processing and mostly washed coffee processors demand fresh cherries that are harvested by selective picking. At the same time, farmers use the fresh red ripe cherries as the basic daily source of income during the harvesting season. Consequently, farmers use selective picking if they are selling their coffee to the washed coffee processors, and once if the farmers harvested the coffee by stripping method, they dry the coffee to sell for unwashed coffee processors.

Nevertheless, the respondents explained that apart from the processing methods, quantity and quality of the coffee to be harvested as well as the speed and cost of harvesting are the determining factors for the choice of harvesting methods. Accordingly, selective picking which consumes much more harvesting time and cost results in high quality product; whereas strip harvesting saves harvesting cost and results in harvesting much more coffee in short period of time yet poor quality products. The result of survey showed that 42.5% and 40% of those farmers using the combination method harvest the crop in two and three cycles; while those farmers who use only strip harvesting or only selective picking, harvest their coffee only once and more than three cycles respectively (Figure 2).

Thus, based on the result of the survey due to the indeterminate nature of coffee plant, a number of harvesting cycles imperatively indicates the exact types of harvesting method performed in the season. For instance if a farmer harvested the coffee only once, that is by strip harvesting while two or more harvesting cycles indicates either the use of the combination of the two methods or only selective picking.

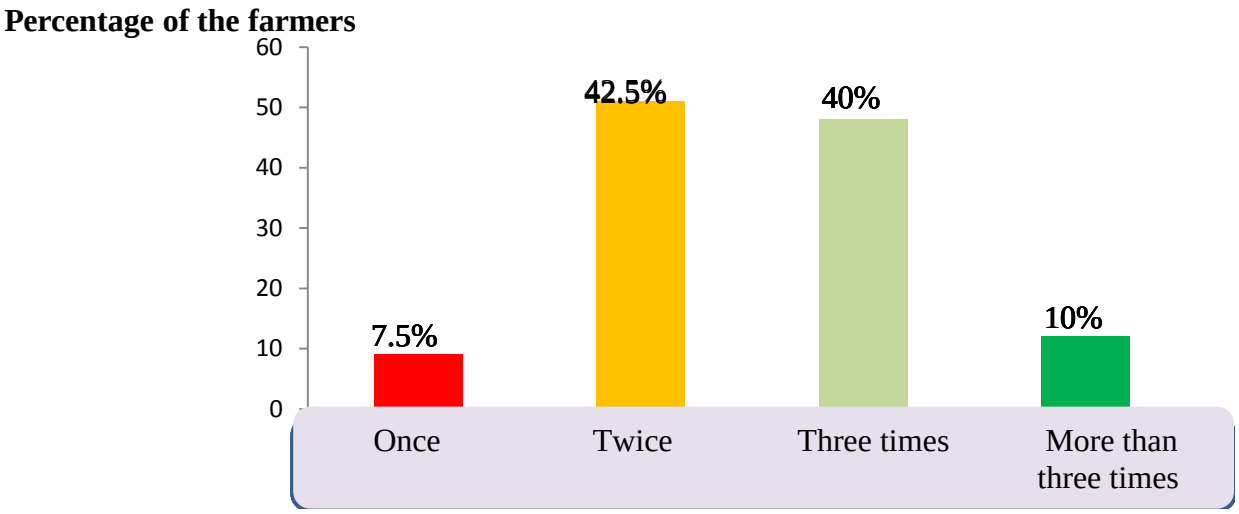


Figure 2 Percentage of farmers and their coffee harvesting cycles during the season

4.1.2. Coffee Fruit Maturity Stage during Harvesting

Coffee fruit maturity stage during harvesting is amongst the most important factors that affecting coffee quality. The findings of current investigation revealed that in *Kercha* district, 49.2% of surveyed HHs harvests their coffee when the cherries attained full red ripe stage; whereas 50.8% of them harvests mixed fruits of different maturity stages (green mature, immature, yellowish, overripe, etc.) when majority of the fruits becomes red ripe stage (Table 2). This finding agrees with the findings reported in the eastern Ethiopia where 55% of the farmers reported to harvest coffee fruit at mixture of different maturity stages (Mohammadsani, 2014).

In addition to the explanation of the surveyed HHs, during focused group discussions (FGDs) and key informants interview, the reasons of harvesting fruits only at full red ripe stage and when the majority becomes red ripe is clarified. Accordingly, cherries are harvested selectively at full red ripe stage primarily to maintain potential flowering buds from damage during harvesting and to ensure the productivity of the mother tree for the next year production. Most farmers focused more on the coffee tree could give reasonable yield in the next year production than the quality of currently harvested product. Besides, since both dry and fresh cherries are sold on the basis of weight, the respondents also elucidated that apart from the higher quality aspects, full red ripe harvested cherries have higher weight than the equivalent volume of mixtures of the fruit. Thus, the higher portion of red ripe cherries within the mixture increases the weight of the fruits harvested at majority red ripe stage.

The current result revealed that in *Kercha* district, only less than 50 percent of the farmers harvest their coffee at appropriate maturity stage that is important not only for quality aspects of the harvested produces but also contributes to the productivity of the mother tree. On the other hand, merely more than 50 percent of the farmers in the district still exercising harvesting fruits at different maturity stage which affects not only the quality of the harvested coffee but also the productivity of the mother tree for the next production season.

4.1.3. Coffee Harvesting Materials

Current assessment clarified that two types of coffee harvesting materials are commonly used in *Kercha* district*;* namely *Kircho* and different types of plastic or polyethylene sheets. The finding revealed that among the surveyed HHs, 35.8% of them use only *kircho,* 2.5% use plastic sheet and 61.7% of them use both coffee harvesting materials (*Kircho* and Plastic sheets). All respondents (Surveyed HHs, FGDs and key informants) explained that they use plastic sheet

only as supplement to *Kircho*. Accordingly, only 4% of the HHs those use both materials uses plastics sheets, whereas 57.7% of them use *Kircho*. Hence, in *Kercha* district majority (93.5%) of the farmers use *Kircho* for harvesting coffee that has no effect on coffee quality. Similar finding was reported in *Gamo Gofa* zone where majority (97.5 %) of the farmers use basket made of bamboo that is *Kircho* in this context (Garo *et al.*, 2016). In addition, Amamo (2014) corroborated that in coffee value chain the cherry is harvested into the basket made up of bamboo tree to control coffee quality in Ethiopia.

In *Kercha* district, the choice of harvesting materials for collecting coffee fruits depends on coffee processing method as well as the relative advantages and disadvantages of the materials during harvesting. *Kircho* is used for collecting coffee fruits by selective picking of full red ripe cherries as well as stripping of berries and cherries of different maturity stage. All of the coffee fruits which stripped over plastic or polyethylene sheets are dried for dry processing. *Kircho* is easy and simple to handle; favorable for both selective picking and stripping methods; relatively no or fewer amounts of foreign materials may be mixed with coffee fruits; saves sorting time; it is used to control coffee quality i.e. free from chemicals, etc...

As drawback, the respondents explained that *kircho* increases harvesting costs and consumes much more harvesting time than a plastic or polyethylene sheet. Plastic or polyethylene sheet lay down under the coffee tree during harvesting and used usually when strip harvesting is favored. Although it is advantageous to harvest huge volume of coffee within short period of time, it results in poor quality coffee. That is not only due to the presence of mixtures of cherries and berries of different maturity stage but also due to the potential contamination with different foreign materials like leaf, twigs, soils, etc..

Table 2 Percentages of the farmers those practiced different coffee harvesting practices in *Kercha* district

Coffee harvesting practices	Frequency	Percent
Harvesting Methods		
Only selective picking	12	10.0
Only strip harvesting	9	7.5
The combination of selective picking and stripping	99	82.5
Total	120	100
Fruit maturity stage during harvest		
Harvesting only when fruits attained full red ripe stage	59	49.2
Harvesting when majority of fruit red ripe	61	50.8
Total	120	100
Harvesting materials		
Kircho	43	35.8
Different types of plastic or polyethylene sheets	3	2.5
Kircho with different types of plastic or polyethylene sheets	74	61.7
Total	120	100

4.1.4. Coffee Harvesting Season

In *Kercha* district, all of the respondents explained that coffee flowering months which usually depends on the rain conditions determines the months in which it will be harvested. That is if the crop receives any shower of rain early at the end of the present harvesting season, it will bloom

soon for the next harvesting season. When coffee harvesting month is coincided with rainy month, there may be the effect on the coffee quality during harvesting and drying in three ways. Primarily, in order to escape from rain, farmers may engage in strip harvesting to harvest bulk of coffee in short period of time. Secondly, since there is a shortage of solar energy due to more cloud during the rainy season, the farmers collect and store their dry cherries before they are completely dried. Thirdly, heavy rain can cause coffee cherries shaded off from the tree and farmers collect the bulk cherries from the ground that contaminated with soil.

The result showed that 73.3% of the surveyed HHs experienced coffee flowering in March whereas 14.2% and 11.7% of them experienced the crop flowering month in February and April respectively. Regarding to the coffee harvesting months, 2.5%, 86.6% and 10.8 % of the HHs harvests their coffee in November, December and January respectively (Figure 3).

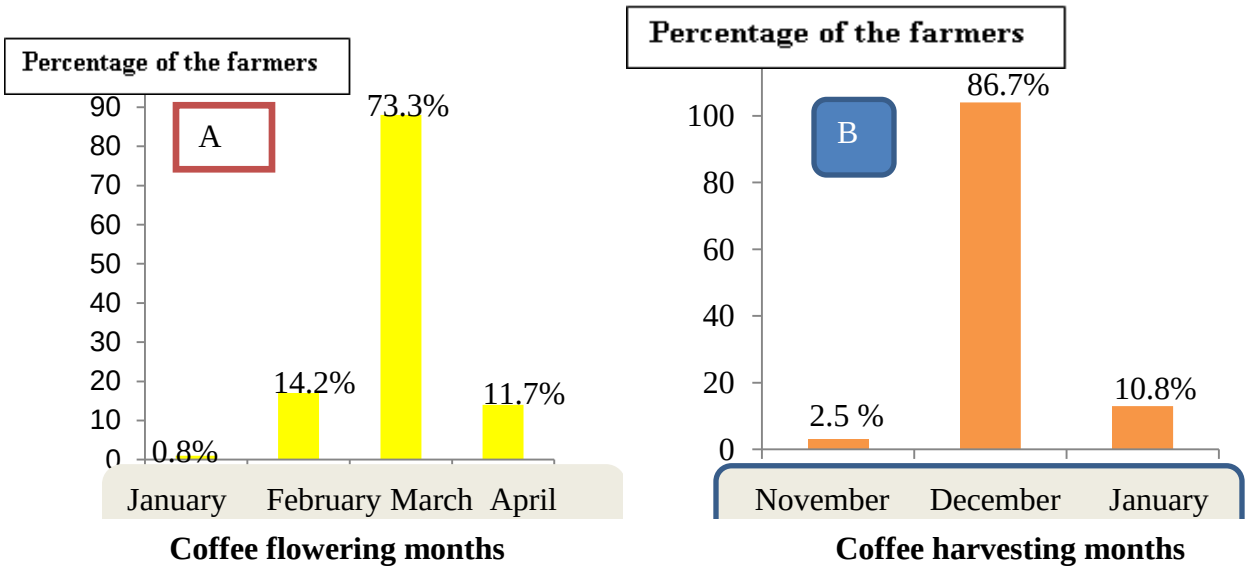


Figure 3 Percentage of the farmers who experienced coffee flowering (A) and harvesting (B) peak month in *Kercha* district

As indicated above (Figure 3), in *Kercha* district, coffee flowering season lies between February and April with March is being the peak flowering month; whereas the harvesting month falls between November and January with December is the peak harvesting month. On the other hand, Ameyu (2014) pointed out that in eastern Ethiopia particularly in *Daro Labu* district of West *Hararghe* zone, April and November is peak coffee flowering and harvesting month respectively. This implies that depending on the climatic conditions (usually rain and temperature) coffee can reach for harvesting within eight to ten months after flowering. Although the variations in coffee harvesting peak months from place to place, and its fluctuation within the year due to the variations in climatic conditions in different part of the country, coffee harvesting peak month did not coincided with rainy month in *Kercha* district.

4.1.5. Labor use and the Role of Gender in Coffee Harvesting

Coffee harvesting is labor intensive activity as it is totally done manually. In *Kercha* district, farmers use both their family and daily hired labors for collecting their coffee. More than half percent (57.5%) of the HHs use both own family and daily labor together; whereas 9.2% and 33.3% of them use only their own family and daily hired labor respectively (Table 3). In FGDs and key informants interview, all of the respondents clarified that majority of the farmers in the district harvest their coffee by using both daily hired labor and own family forces.

Traditionally, since gender is sex based labor division practice, it is important to know the role of gender in coffee harvesting in *Kercha* district. More than three-fourth (75.8%) of the surveyed HHs harvest their coffee using both males and females; while 20% and 4.2% of them harvest the crop by using only males and females respectively **(**Table 3). It is also clarified both in FGDs and key informants interview, unlike other activities of the crop (weeding, seed preparation, nursery site preparation, loading and unloading, etc), females involve in coffee harvesting.

This indicates that in *Kercha* district, usually there is no gender discrimination for coffee harvesting due to the traditionally sex based labor division. Ameyu (2014) corroborated the dominance of males than females in coffee quality and postharvest management practices in West *Hararghe* zone of eastern Ethiopia. Similarly, Abadiga (2010) reported that in western Ethiopia particularly in *Jimma* zone, male headed HHs were positively related to the adoption of coffee quality and postharvest management practices than female headed HHs. Therefore, this result is in consistent with the previous findings. However, contradicting with the current result, it was reported that except loading and unloading, coffee cherry collecting and transporting in Ethiopia is mostly performed by females groups (Amamo, 2014).

Table 3 Percentages of the farmers those use different labor and gender for coffee harvesting

	Frequency	Percent
Gender involvement		
Only males	24	20
Only females	5	4.2
Both males and females	91	75.8
Total	120	100
Labor use		
Only own family	11	9.2
Only daily hired labors	40	33.3
Both own family and daily hired	69	57.5
Total	120	100

4.2. Postharvest Management Practices of Unwashed Coffee

4.2.1. Drying Structures for Unwashed Coffee

Unlike washed coffee, unwashed coffee is dried with its skin parchment before processing. In *Kercha* district, unwashed coffee drying structures were investigated thoroughly at the farmers' and unwashed coffee processors' level. Accordingly, 75% of the surveyed HHs dries their coffee on raised bed bamboo mat, whereas 25% of the HHs use different types of plastics or polyethylene sheets laying on bed or on the ground (Table 4). This implies that majority of famers in *Kercha* district dry their coffee on bamboo mat bed while only about one- fourth of them use different types of plastic or poly ethylene sheets. Though not identified during the survey, from the FGDs and key informants' interview, it is clarified that even some farmers started to use raised bed mesh wire; whereas nobody dries coffee on bare ground in *Kercha* district.

Similarly, Abadiga (2010) reported that majority (61.2%) of the farmers in Western Ethiopia dry their coffee on wooden and bamboo made raised bed which maintains the inherent quality of coffee. However, previously it was reported that about 69.4% of coffee growing farmers in southern Ethiopia dried their coffee on the bare ground leveled with mud and cow dung (Garo *et al.*, 2016). Also, current finding disagrees with the findings of Mohammedsani who reported that majority of the farmers in eastern Ethiopia dried their coffee on the ground floor or plastic sheets (Mohammedsani, 2014). Thus, in *Kercha* district, coffee drying structures are not amongst the major postharvest management problems that affecting the inherent quality of unwashed coffee.

According to the farmers' respondents, both raised bed bamboo mat and polyethylene or plastic sheets, each have distinctive relative advantages and disadvantages that ascertain their

preferences by the farmers. Some of the advantages of bamboo mat bed those mentioned by the farmers are 1) bamboo mat is more preferable to control coffee quality i.e the dried cherries are bright having an attractive black color and good smell (fragrance). 2) It has good aeration so that mold development can be prevented. 3) It does not retain rain water and as such it hastens the drying period. On the other hand, lack of durability, ever increasing price and time required for the preparation of the bed are amongst the draw backs of bamboo mat bed mentioned by the respondents. The respondents explained that although plastic sheet is more durable than bamboo mat bed, it results in poor quality cherries.

At the processors' level, the information extracted from the key informants' interview indicates that they use drying structures like raised bed mesh wires, raised bed plastic net, cemented floor and polyethylene or plastic sheets. These structures are observed also during the visit at the coffee processing sites. Processors usually use mesh wires and/or plastic net to dry temporarily fresh cherries immediately after harvest. Cemented floor and/or polyethylene sheets used for the final drying of the cherries those are partially dried on the mesh wires bed and/ or plastic net bed. The processors also use the structures to dry and clean the cherries those are not completely dried and cleaned at the farmers' level for the second time.

Therefore, cemented floor and/or polyethylene sheet are necessarily important for the processors to dry and clean huge volume of cherries within a short period of time. Raised bed mesh wire and cemented floor are more common at unwashed coffee processing site in *Kercha* district than plastic net and polyethylene/plastic sheet. This is in line with the previous findings which pointed out that raised bed mesh wire, plastic sheets and cemented floor were the coffee drying structures used by unwashed coffee processors in western and southern Ethiopia (Abadiga, 2010; Garo *et al.,* 2016).

4.2.2. Drying, Stirring and Sorting of Unwashed Coffee

Drying of coffee cherries which is carried out before dry processing of the coffee is amongst the most imperative postharvest practices of the coffee. For unwashed coffee production, the cherries are dried with parchment before dry processing. During drying of the cherries, usually stirring and sorting of the cherries operated simultaneously to ensure uniform and fast drying and to prevent the development of mold on the cherries. This indicates that the level of moisture content of the coffee is the important factor to be considered to maintain the quality of the coffee during postharvest management. According to the current ECX (2018) standard, to control its inherent quality, moisture contents of coffee should be maintained at 11.5%.

In *Kercha* district, according to the respondents' explanations, totally all the farmers use the traditional methods of evaluating the dryness of the cherries by estimating the moisture content than measuring the exact moisture content of the cherries. Accordingly, two traditional methods are practiced complementarily at the farmers' level *viz:* crushing the cherries in between teeth and/or the sound of the dry cherries.

Up on crushing if the parchment easily released and even cut of the bean is hard, the coffee is considered as dried well and acceptable but considered as not dried otherwise. On the other hand, while judging by the sound of the dry cherries, the cherries are considered as well dried when dry cherries grasped in between the palm gave a specific sound revealed as ''sha…sha…sha….''. Some processors occasionally use digital or modern moisture tester machine apart from the traditional methods. Regarding the method of crushing the cherries in between teeth, similar result was reported previously in southern Ethiopia (Garo *et al.,* 2016).

During drying the cherries, stirring is an important activity in order to ensure uniform drying and hasten the drying period. The result indicates that the majority (55%) of the farmers in *Kercha* district practiced stirring three times in a day while drying the cherries (Figure 4). The thickness of the layered cherries may contribute for different level of moisture content. However, all of the respondents expounded that the layer thickness of the drying cherries evaluated simply by visual inspection as lightness or bulkiness rather than taking the exact measurement.

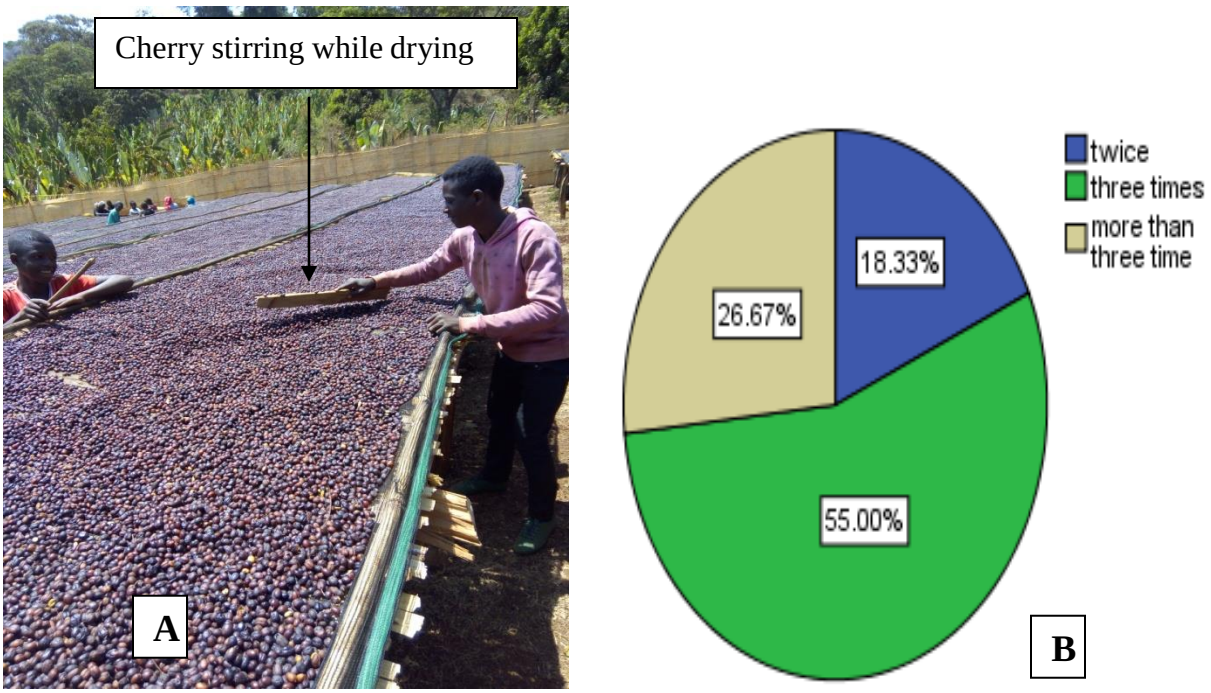


Figure 4 Farmer stirring unwashed coffee (A) and the percentages of farmers (B) stirring coffee per day while drying

Sorting and/or cleaning of coffee are the important practices both before and after processing of unwashed coffee. This is done at two stages as primary sorting and secondary sorting stages before and after dry processing of unwashed coffee respectively. While drying the cherries, defective coffee fruits (immature and deteriorated coffee fruit), any foreign materials (leaf, twig, stone, fruit of other trees, etc.) are removed a head of processing.

On the other hand, after dry processing, sorting of beans is the immediate important activity to remove different primary defects (full black beans, full sour beans, fungus developed beans, etc.) and secondary defects (immature beans, withered beans, starved beans, partially broken beans) from the coffee beans (Figure 5). In postharvest management of unwashed coffee, drying and stirring are exclusively important activities before the cherries processing whereas sorting which is common at the processors' level is an important activity both ahead of processing and soon after processing. Hence, in *Kercha* district, in unwashed coffee production, drying and stirring are absolutely related to the cherries whereas sorting is related to both coffee cherries and beans, usually performed by females groups.

Figure 5. Illustrations of the stages of sorting of unwashed coffee

4.2.3. Packing and Storage of Unwashed Coffee

Packing and storage materials of unwashed coffee which are amongst the important postharvest management practices are investigated both at the level of coffee growers and unwashed coffee processors. The result showed that at the level of both farmers and processors, dry cherries are completely packed and stored into polyethylene sack while the beans after processing are packed into jute sack. According to the respondents' explanation, this is due to lack of the jute/sisal sacks besides its high prices. Differently from this, it was reported that in eastern Ethiopia majority of farmers use polyethylene sack to pack dry coffee cherries, whereas the processors use the recommended jute/sisal sack to pack both coffee cherries and beans before and after processing respectively (Mohammedsani, 2014). In *Kercha* district, since polyethylene sacks which are not recommended are the only dry coffee cherries packing materials in use, it can be understood that packing materials are amongst the major postharvest management problems that affecting the coffee quality.

Coffee storage conditions/facilities affect its quality by facilitating mold development through attracting the moisture from the surrounding or through the direct contact of the beans/cherries with potential contaminants. About 82.5% of the surveyed HHs stores dry coffee cherries in their dwelling home yet in the separate class, whereas 17.5% of them use the separate store room to store the coffee (Table 4). The respondents explained that, usually, plastic sheet laid down under the sack packed with dry coffee cherries to prevent its direct contact with the ground and from termite that would built mound in the coffee during the storage time. The respondents expounded that usually there was mold development during storage and that mold development becomes apparent during the time when dry cherries taken out for marketing.

Accordingly, during storage 54.2% of the surveyed HHs usually detected mold developed on their cherries, whereas 45.8% of them did not. The mold develops on those cherries stored before completing their drying stage as well as when storage conditions facilitate its development (Poltronieri and Rossi, 2016). For instance lack of aeration of the storage room which is common particularly at the farmers' level can facilitate mold development. From this, it can be understood that in *Kercha* district, storage condition is amongst the major postharvest management problems that affecting the quality of unwashed coffee because majority of farmers store the produce within their dwelling home and usually detect the mold developed on their coffee cherries.

Storage duration of the produce is the important postharvest management practice that determines the produce quality. According to the respondents' explanations, the storage duration for dry coffee cherries usually depends on the coffee market prices conditions. However, some respondents clarified that storing coffee for a certain period of time also practiced as saving money in terms of the produce regardless of the future prices fluctuation.

The result of current study revealed that 98.3% of the surveyed HHs stores their coffee for less than four months, and only 1.7% of them store the cherries for more than four but less than six months (Table 4). About 88.3% and 11.7% of the HHs preferred these range of the storage durations with an expectation of coffee price increment in the future and saving money in terms coffee respectively. This is in consistency with the previous findings where majority of the farmers in southern and eastern part of Ethiopia stored their dry coffee cherries for less than a year (Garo *et al.,* 2016; Mohammedsani, 2014). Hence, as the generally accepted storage time for coffee under normal conditions is up to one year, storage duration is not as such major postharvest problem of unwashed coffee in *Kercha* district.

Table 4 Percentages of the farmers those practiced different postharvest management practices of unwashed coffee cherries

Unwashed coffee cherries postharvest management practices	Frequency	Percent
Unwashed coffee cherries drying structures		
Bamboo mat bed	90	75
Different form of plastics/polyethylene sheets	30	25
Packing materials of the coffee cherries		
Polyethylene sack	120	100
Storage place of the dried cherries		
Own living house	99	82.5
Separate room	21	17.5
Storage duration of the cherries		
Stored for 1-4 months	118	98.3
Stored for 5-6 months	2	1.7
Coffee cherries transaction place		
Primary level coffee transaction center	80	66.7
Other places like at own home	40	33.3
Total	120	100

At the level of the processors, dry coffee cherries and beans stored in the same yet different sides of coffee processing room. Hence, there is no separate store room for dry coffee cherries and beans because once it is produced, the bean will immediately transported to the central market. The key informants clarified that the processing room for unwashed coffee processing serves dual purposes as coffee processing and storage room. Besides, other post-processing activity of the coffee like secondary stage sorting is performed in the room (Appendix Illustration 3).

4.2.4. Unwashed Coffee Processing

In unwashed coffee processing, the natural or sun dried cherries processed by dry processing method to produce coffee beans. In the processing method, the cherries which dried with intact pulp and mucilage husked with crushing machine. During milling the cherries, vibrator is one of the most important parts of the processing machine that separates the husk from the beans by vibration.

The respondents explained that washed coffee and unwashed coffee processing machine is locally established since 1995 and 1999 respectively in *Kercha* district. Before that the cherries had been processed in *Bule Hora* district which is one of the neighboring districts of *Kercha*. This revealed that although coffee production has long year history in the district, unwashed coffee processing is started about two decade ago in *Kercha* district. Currently for dry and wet processing methods, there is 45% and 55% of coffee processing machines in the district respectively. The information obtained from the respective office of the district showed that unwashed coffee represents 50-60% of the total coffee processed in *Kercha* district. This is in line with the previous reports which corroborated that majority (71%) of coffee processed in Ethiopia is unwashed coffee (Abu and Teddy, 2013; Mohammedsani, 2017; Seifu *et al*., 2016).

All the respondents explained that unlike at the level of the processors, coffee beans do not produced for the marketing purpose at the level of the farmers in *Kercha* district. For home consumption of the coffee, the husk is completely removed by traditional mortar and pestle thereby through manual winnowing and cleaning, husk separated from clean beans. This is also confirmed by visual observation during the field visit.

4.2.5. Transportation of Unwashed Coffee

Transportation is amongst the most important postharvest management practices where coffee quality could be affected. Coffee quality can be affected during loading and unloading, transportation, etc., through direct contact and/or attraction of potential contaminants. The respondents explained that, in *Kercha* district usually transportation of unwashed coffee is from the late February to June. This indicates that the transportation time coincides with rainy season. Apart from the hygroscopic nature of coffee, the moisture content of dry coffee cherries may fluctuate due to the incidence of rain during transportation to primary level coffee transaction center (PLCTC). This may facilitate mold development even on the cherries that were properly harvested and handled.

Also the respondents pointed out that more focus is given to the fresh cherries and coffee beans quality than dry cherries. This is because dry coffee cherries have protective skin cover besides its lower water and sugary mucilage content. Unlike washed coffee where only the external skin (pulp) is removed and the middle skin (parchment skin) is not removed during processing; in unwashed coffee processing, both pulp and parchment skin removed once in hulling. This makes the naked beans of unwashed coffee to be more sensitive to the potential contaminants like moisture absorption or loss, dust attraction, etc., than parchment beans of washed coffee during transportation.

During the key informants' interview, it is clarified that usually up on the arrival at the central market (ECX), unwashed coffee whose moisture content level was at the standardized level (11.5%) during dispatching from the district showed a raise in moisture content level. ECX has opened its new branch recently at 38 Km away from *Kercha* district on May 12, 2018 in *Bule Hora* town, the capital city of West *Guji* zone. Before opening of ECX branch there, the coffee produced in the district sent to *Hawassa* branch ECX which far 212 Km from *Kercha* district. Hence, the opening of ECX enterprise nearby to the district may plays vital roles in controlling coffee quality by reducing the possible risks of the potential contaminants like dust, and moisture gain or loss due to long distance transportation.

4.2.6. Unwashed Coffee Marketing

According to the rule and regulation of coffee marketing in Ethiopia, in order to regulate coffee marketing, quality and quantity, there is a typical transaction centers where coffee sold to the commercial market, and traceable to its growing origin. Hence, coffee transaction is performed in the three sequential chains starting from the principal producers (the farmers) until it reaches to the principal distributors (the exporters).

These centers include Primary Level Coffee Transaction Center (PLCTC), Ethiopian Commodity Exchange Center (ECX) and International Coffee Market (ICM). Amamo (2014) reported that there was about 979 PLCTC and 8 ECX centers for coffee marketing in Ethiopia. An ECX is a public market facilitating institution that was established in 2008 with the help of the United States Aid for the International Development (USAID) to eliminate the huge number of middlemen/brokers involved in coffee distribution, and to enable coffee farmers benefit from prevailing market prices (Abu and Teddy, 2013).

The ECX center is the place where the transaction of coffee beans is performed between coffee suppliers/ processors and exporters; whereas ICM is the place where the transaction of the produce performed between the exporters and coffee importers countries i.e. Coffee auction.

It is clarified by key informants' interview that more than 80% of the total coffee produced in *Kercha* district sent to the central market whereas the remaining 20% is used for local consumption. In the district, the byproduct of unwashed coffee (husk) and mature coffee leaves are used to prepare a hot drinking beverage. This is in consistent with the previous findings in southern Ethiopia where majority of the farmers use coffee leaves and husks as substitutes for coffee as a hot drinking beverage (Garo *et al.,* 2016).

In *Kercha* district, there is about 43 PLCTC where the transaction of fresh and/or dry cherries undertaken between the farmers and coffee processors or suppliers. The number of PLCTC (43) is higher than the number of total coffee producing rural *kebeles* (23) in the district. This indicates that at least there is one PLCTC in each coffee producing *kebele* depending on the volume of coffee produced and area coverage of the *kebele*. Although a substantial number of PLCTC exists in the district, unlike fresh coffee cherries, not all dry coffee cherries (jenfal buna) transacted at the center.

In the district, out of the surveyed HHs, 66.7% of them sell their dry coffee cherries at PLCTC, whereas 33.3% of them sell the produce at other places like their own home to avoid transportation and transaction costs (Table 4). Some farmers sell their dry coffee cherries at their own home after negotiating on the price with the processors or middle men. Also during FGDs and key informants interview, it is clarified that almost all of fresh cherries are totally marketed at PLCTC. However, still there are substantial numbers of farmers and processors who

undertook the transaction at the places other than legally established PLCTC. Previous finding particularly in eastern Ethiopia reported that majority of the farmers in *Daro Labu* district of west *Hararghe* zone sold their coffee in village market (Mohammedsani, 2014).

In *Kercha* district, both fresh and dry cherries are purchased at PLCTC by three types of coffee buyers: namely primary farmers' cooperative, private coffee processors/ suppliers and middle men. Legal middle men act on the behalf of those private coffee processors who could not avail themselves directly in the transaction. Majorities (55%) of the surveyed HHs sell their cherries directly to the processors whereas only about 5% of them sell to the primary farmers' cooperative (Figure 6). This implies that in the district majority of the farmers (60%) sell dry coffee cherries to the certified processors. This disagrees with the recent findings in *Gamo Gofa* zone, southern Ethiopia which stated that majority of the respondents (53.1%) argued that majority of the coffee produced in the area sold to the illegal traders and left the area through smuggling (Garo *et al.,* 2016).

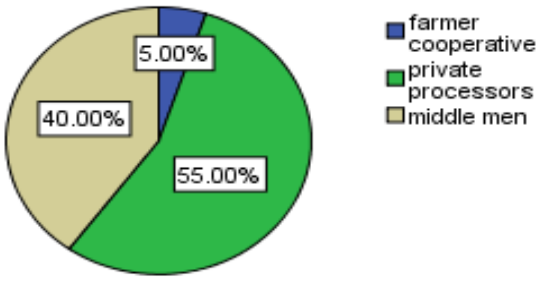


Figure 6 Percentages of dry coffee cherries purchasers at the primary level coffee transaction center

Almost all of the respondents especially the farmers complain against the involvement of the middle men in coffee transaction. Farmers' respondents explained that the involvement of middle men affect coffee quality not only by mixing of properly prepared coffee cherries with poor quality cherries but also bought good quality cherries at the same lower price to poor quality cherries. This discourages the farmers to give more attention to the coffee quality during harvesting and postharvest management which finally affect the overall coffee quality.

Similarly, the processors complain that the middle men brought back mixture of good and poor quality cherries of different moisture level to them. Besides, middlemen undertook price cheating by mentioning as if they were bought the produce at higher price up on delivering it to the processors yet actually they bought at a lower price from the farmers. Hence, middle men usually more focused on the quantity of coffee and their personal interest than coffee quality and the farmers' as well as the processors' benefit.

According to the result from the interviewed key informants, 50% of the coffee processors buy both fresh and dry cherries whereas 50% of them collect only dry cherries to produce unwashed coffee beans. On the other hand, it was stated that in eastern Ethiopia majority (67.3%) of dry coffee processors bought both fresh and dry cherry of different moisture level for unwashed coffee beans production (Mohammedsani, 2014). Those respondents who have collected both fresh and dry cherries responded that they buy selectively picked fresh cherries thereby dried properly for unwashed coffee beans production. In addition, they seek and communicate with the farmers to prepare good coffee as they would take a bulk of cherries once at the market price from the home of the farmers. The advantage of the farmers from this is only the reduced expenses for transportation and transaction rather than the premium price of properly harvested, prepared and handled cherries.

The respondents pointed out that the usual coffee price fluctuation in addition to its low price is amongst the most important coffee marketing constraints that affecting its quality in *Kercha* district. Coffee price fluctuation happened not only due to the imbalance between demand and supply but also due to coffee quality matter. There is variation in global coffee production from year to year due to variation in climatic conditions, field management, diseases and insect pests' incidences, etc.

The price decision for coffee cherries at PLCTC is totally by coffee processors whereas at ECX bidding system is an "Open Cry Out" system where sellers and buyers meet on an open trading floor to negotiate and finalize the sales deals. Depending on market information passed by ECX, the processors set their own price of the day and posted at the PLCTC. This is in line with the earlier finding where farmers were market price takers and information takers rather than the price maker and the market information holders (Amamo, 2014).

Usually coffee suppliers/ processors call meeting to set only the beginning price without the involvement of farmers' representative. Accordingly, usually the average beginning price per kilogram of dry coffee cherry set as 20 ETB (Ethiopian Birr). However, usually there is slightly the average price increment yet not more than 35 ETB/Kg from the onset of unwashed coffee production up to its closing. This is due to the reason that those processors/suppliers who are previously used to buy fresh cherries for unwashed coffee production also involve in purchasing of dry coffee cherries. The farmers complain for that they do not get fair price that covers their cost of production incurred up on good quality coffee preparation. Hence, majority of the farmers sell good quality coffee at the same lower price with poor quality coffee. This indicates that there is no premium price for properly harvested and handled coffee in *Kercha* district.

This is in agreement with the previous assessment which stated that there is no premium price for good quality coffee in Ethiopia (Mohammedsani, 2014). Therefore, there are many marketing constraints of unwashed coffee like huge numbers of illegal collectors, usually fluctuating and low price, lack of premium price, lack of market information providing institutions in the district, etc.,. In *Kercha* district, coffee is transacted in the following coffee marketing value chains (Figure 7).

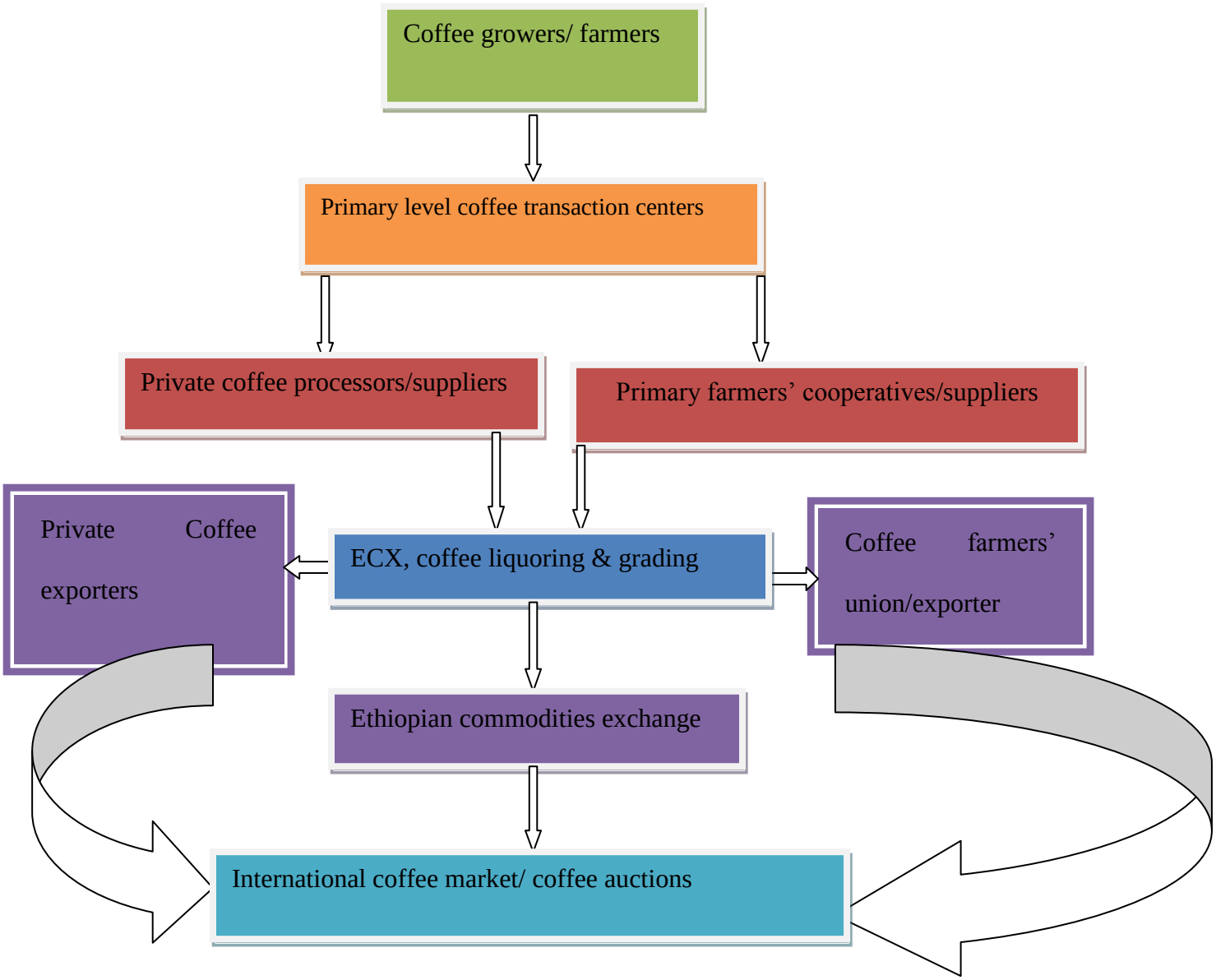


Figure 7 Current coffee marketing value chains in *Kercha* district

4.2.7. Unwashed Coffee Quality Inspection

Coffee quality inspection performed consecutively throughout harvesting up to the export level. Nevertheless, commonly more attention is given to the quality analysis of coffee beans than dry coffee cherries. Accordingly, the quality of coffee beans assessed primarily and secondarily during dispatching of the coffee from the district and up on its arrival at the central market, Ethiopia commodity exchange (ECX) enterprise respectively.

In *Kercha* district, during the primary coffee quality analysis that is at the level of the district, moisture content level of the coffee beans and different visual defects in the beans used as the important parameters. At the district level, there is no counting or measuring of the amount of the different visually detectable defects in the beans though the moisture content level of the beans measured just during the dispatching of the coffee to the central market. 'Coffee quality control and marketing expert' has the responsibility of assessing the coffee quality at the district level. Dispatching will be disqualified if much more defects are detected visually in the coffee beans as well as when the moisture content level of the beans dropped below or raised above the standardized level (11.5%). Therefore, unwashed coffee quality evaluation at the *Kercha* district level is based on the coffee beans moisture level test and the visual assessment of different defects in the beans.

On the other hand, during the secondary quality analysis which is performed at ECX enterprise, both raw bean and cup quality analysis is important. According to ECX (2018), the standardized important physical attributes for the evaluation of the quality of unwashed coffee includes primary defects, secondary defects and odor. Each of the first two parameters scored out of 15%, whereas the latter represents 10%, and summed to give 40% share of the raw bean coffee quality evaluation to the overall quality.

Primary defects are visually detected defects in the beans and measured by counting. Similarly, secondary defects are detected visually yet evaluated by the weight of the defected beans. Unlike in the raw bean quality evaluation, in the organoleptic quality analysis, the beans completely subjected to the chemical change. Hence, roasting, grinding, brewing and cupping of the coffee are necessarily the important activities ahead of performing the cup quality evaluation that shares 60% of the overall coffee quality score. Generally, quality inspection is importantly undertaken in each and every sequential postharvest management activities of unwashed coffee where the overall quality of the coffee could be critically affected unless key attention is given (Figure 8).

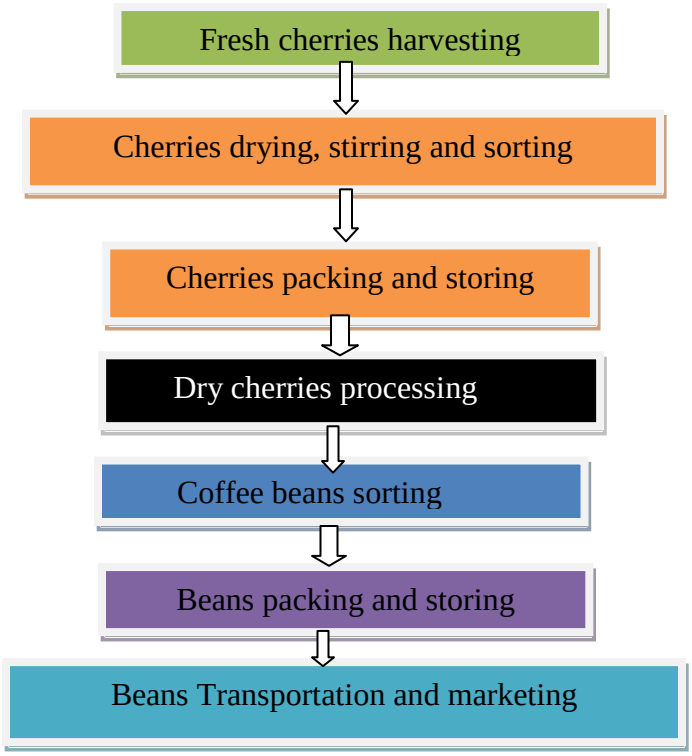


Figure7 The sequential postharvest activities of unwashed coffee in *Kercha* district

4.3. The Effects of Harvesting Methods and Drying Structures on Unwashed Coffee Quality

4.3.1. The Odor of Unwashed Coffee Raw Beans

The interaction effect of the two factors (coffee harvesting methods and drying structures) and the main effect of the harvesting method showed no significance ($P>0.05$) effect on the odor of unwashed coffee beans (Appendix Table 3). However, the main effect of the drying structures showed significance effect ($P<0.0001$) on the odor of unwashed coffee beans. Accordingly, bare ground resulted in lower mean (8.0) value whereas all the other drying structures (cemented floor, bamboo mat bed and mesh wire bed) produced similar higher mean (10.0) values for the odor of the coffee beans (Table 5). This implies that the odor of unwashed coffee beans is highly sensitive to the potential contaminants like dust due to the hygroscopic nature of coffee (Seifu *et al*., 2016; Tsagaye *et al.*, 2014).

According to ECX (2018) standard of unwashed coffee quality evaluation, there are different quality descriptions and values set for the bean odor quality like clean, fair clean, trace, light, moderate and strong. Hence, coffee beans with clean odor was obtained when coffee cherries harvested by either of the two harvesting methods (strip or selective pick) dried on the cemented floor; mesh wire bed and bamboo mat bed whereas the cherries dried on the bare ground resulted in the coffee beans with fair clean odor (Appendix Table 1).

4.3.2. The Primary Defects in the Raw Coffee Beans

The interactions effect of the harvesting methods and the drying structures as well as drying structure as main factor revealed significance differences ($P< 0.05$) on the quality of the raw beans for number of primary defects in the coffee beans (Appendix Table 3). However, harvesting method had no significance ($P> 0.05$) effect on the amount of primary defects. Except strip harvesting with drying on bare ground which resulted in lower mean (13.0) value, the higher similar mean (15.0) values were recorded for all treatments (Table 5). Previously it was reported that the presence of foreign materials of non-coffee origin (soil, stone, non-coffee fruit, etc.); foreign materials of non-bean origin, such as pieces of parchment or husk; abnormal beans for visual appearance, such as black beans in the coffee beans are highly affecting coffee quality (Seifu *et al*., 2016).

The chance of contamination with the coffee born defects and foreign materials is increased when the coffee cherries harvested by stripping method and dried on the bare ground. The result implies that the observed high amount of primary defects such as full black beans and soil in the raw coffee beans are resulted from strip harvesting and drying on bare ground. Since strip harvesting results in fruits with different maturity stage such as immature and overripe fruits, the amount of abnormal beans for visual appearance like black beans are increased. This increases the amount of primary defects, and as the number of primary defects in the beans increases, the quality of the beans will decrease. Hence, harvesting coffee by stripping method and drying on bare ground influences its raw bean quality by increasing the amount of primary defects in the coffee beans.

4.3.3. The Secondary Defects in the Raw Coffee Beans

There was no significant effect (P>0.05) of the interactions between coffee harvesting methods and drying structures on the raw bean quality for the detection of the percentage of secondary defects in unwashed coffee beans (Appendix Table 3). Only the main effect of the harvesting method resulted in significantly difference ($P<0.0001$) in the proportion of the secondary defects in the coffee beans harvested by striping and selective picking methods. The higher mean (15.0) value of the quality of the raw beans for the incidences of the defects in the beans was recorded from the selectively picked cherries whereas the lower mean (6.0) value was obtained for the strip harvested beans (Table 5). The current result showed that strip harvesting increased the amount of secondary defects due to indiscriminate harvesting of coffee cherries of different maturity stages. Those cherries harvested at an immature and over ripe stage will result in defective beans.

Previous report indicated that as the proportion of coffee bean origin defects (abnormal beans) such as immature beans, withered beans, broken beans and partial black beans increased in the beans, the quality of the bean will be decreased (Seifu *et al.*, 2016). This finding clarified that harvesting coffee by stripping method results in 60% loss in the expected value (15%) for the beans quality due to the increased proportion of secondary defects in the beans. This is because the maximum standardized value for the quality of raw coffee beans for the incidences of the secondary defects in the beans is 15%, and strip harvested beans resulted only in 6% of this value due to the increased proportion of the secondary defects in the beans. According to the current ECX (2018) standard for unwashed coffee quality evaluation, 20% of secondary defects are detected in the coffee beans harvested by strip harvesting method though only 5% of the defects were observed in the beans when cherries were picked by selective harvesting method.

4.3.4. The Acidity of Unwashed Coffee Liquor

The main effect of harvesting methods ($P<0.0001$) and drying structures ($P < 0.05$) as well as the interaction effect of the two factors revealed significant ($P<0.05$) differences for the liquor acidity of unwashed coffee (Appendix Table 3). Except with bamboo mat bed, strip harvesting with all the others drying structures (bare ground, mesh wire bed and cemented floor) resulted in lower mean (9.0) value making the coffee medium quality in terms of acidity (Table 5). The higher mean (12.0) value of the acidity was obtained when selectively picked cherries are dried on all the drying structures, and make the coffee beans more enjoyable.

Previous study reported that immature coffee bean mainly increases its liquor astringency, and sour bean with unpleasant characteristics is produced when coffee cherries contaminated with soil like drying it on bare ground (Daniels, 2009). The acidity or the bitterness of coffee liquor which is an important aspect of its liquor quality is resulted due to the presence of organic acids such as acetic, formic, malic, and citric and lactic acids as well as chlorogenic and quinic acids (Muhammad *et al.,* 2017). Chlorogenic acids cause the acids reflux that is sometimes experienced by coffee drinkers and confer astringency, bitterness and acidity to the coffee brew.

According to current ECX standard of unwashed coffee quality evaluation, high intensity of acidity in coffee liquor is enjoyable, and the maximum intensity is regarded as pointed acidity. However, all of the treatments revealed the acidity intensity of the liquor that ranges from medium up to medium- pointed acidity (Appendix Table 1). The current study revealed that acidity of unwashed coffee is mainly affected by the harvesting method than the drying structures as the acidity of unwashed coffee liquor of the selectively picked coffee cherries was not affected even when the cherries dried on the bare ground.

The presence of defect beans such as full black beans, broken beans, immature beans, overripe black beans, etc. affect the liquor quality of unwashed coffee. Therefore, higher amount of primary and secondary defects which are mainly resulted from strip harvesting and bare ground affect not only raw bean physical quality but also the liquor cup quality by affecting its acidity.

4.3.5. The Body of Unwashed Coffee Liquor

The body of coffee liquor is the feeling that it has in our mouth. It is a measure of coffee brew viscosity and largely created by coffee beans' oils and organic acids extracted during the brewing process. The interactions of the two harvesting methods and four drying structures showed significant effect ($P<0.05$) on the body of unwashed coffee liquor (Appendix Table 3). The higher mean (12.0) value for unwashed coffee body is obtained only when selectively picked cherries dried on mesh wire bed, bamboo mat bed and cemented floor whereas the lower (9.0) mean value is observed when strip harvested cherries dried on all the drying structures (Table 5).

The result showed that selectively picked cherries will have reduced body if they are dried on the bare ground. This may be because apart from water-insolubility of oil particle which is responsible for coffee liquor body, only small amount of oil is extracted by high temperature of the boiled water and present in the brew as emulsion (Muhammad *et al.*, 2017).

4.3.6. The Cup Cleanness of Unwashed Coffee Liquor

Unlike the other parameters of unwashed coffee quality, the harvesting methods and/or the drying structures totally resulted in the expected maximum (15.0) value for the coffee cup cleanness (Table 5). Therefore, ANOVA revealed no variation in the values of cup cleanness when the coffee harvested by the two harvesting methods and dried on all the four drying structures. Hence, the harvesting methods and the drying structures do not affect the cup cleanness of unwashed coffee quality.

4.3.7. The Flavor of Unwashed Coffee Liquor

The interaction of the coffee harvesting methods and the drying structures has significant effect ($P<0.05$) on the flavor of unwashed coffee liquor (Appendix Table 3). At the same time, each of the factors showed significant effect ($P<0.0001$) on the flavor of the coffee. Strip harvesting and drying on both bare ground and cemented floor resulted in the lowest similar mean (6.0) value whereas selective picking with all the drying structures except with bare ground resulted in similar highest mean (12.0) value (Table 5).

Previous finding reported that immature berries and overripe cherries as resulted from strip harvesting produces very bad off-tastes flavor. According to Muhammad *et al. (*2017), this is because in addition to the hygroscopic nature of coffee bean, small amount volatile compounds (furans, pyridines, pyrrols, aldehydes and melanoidins) which are responsible for coffee liquor flavor are produced from immature beans. In addition, overripe cherries that over-fermented on the tree causes bad off-taste flavor in coffee cup. As the current ECX (2018) standard for unwashed coffee quality evaluation, the flavor quality of the coffee valued 6%, 9%, 12% and 15% is described as fair, average, fair good and good, respectively.

However, the expected highest (15%) value of good quality for flavor is not observed with selective picking of only red ripe cherries and drying even on the structures other than bare ground. The result indicated that when strip harvesting combined with bare ground or cemented floor, there is 60% loss in the flavor of unwashed coffee liquor. Therefore, the harvesting methods and the drying structures together highly affected the flavor of unwashed coffee liquor.

Table 5 The means values for the standardized parameters of unwashed coffee quality as affected by harvesting methods and drying structures

Treatments	The standardized parameters for unwashed coffee quality						
	Odor (10%)	Primary Defects (15%)	Secondary Defects (15%)	Acidity (15%)	Body (15%)	Cup Clean (15%)	Flavor (15%)
Strip -ground	8b	13b	6b	9b	9b	15a	6c
Strip-Cement	10a	15a	7b	9b	9b	15a	6c
Strip-Mesh	10a	15a	6b	9b	9b	15a	8b
Strip-Bamboo	10a	15a	8b	11a	9b	15a	9b
Select- ground	8b	15a	12a	12a	10b	15a	9b
Select-Cement	10a	15a	12a	12a	12a	15a	12a
Select-Mesh	10a	15a	15a	12a	12a	15a	12a
Select-Bamboo	10a	15a	14a	12a	12a	15a	12a
LSD (0.05)	**0.7066**	**1.06**	**3.1799**	**1.06**	**1.06**	**0**	**1.06**
CV (%)	**4.3**	**4.2**	**18.4**	**5.7**	**5.97**	**0**	**6.62**

NB: The means with the same letter in the columns are statistically not significantly different

4.3.8. The Total Raw Quality of Unwashed Coffee Beans

The total raw quality of unwashed coffee is resulted from each physical quality attributes of the coffee beans like odor and values of the beans for the defects. The interaction effect of coffee harvesting methods and drying structures showed no significant effect ($P>0.05$) on the total raw quality of the coffee beans (Appendix Table 3). Only the main effect of the harvesting method significantly affected ($P<0.0001$) the total raw bean quality. The higher mean (37.75) value for the total raw bean quality is obtained with selective picking of only red ripe cherries while strip harvesting resulted in the lower mean (30.92) value for the total raw beans quality of unwashed coffee (Table 6). This is due to the decreased amount of the defects in the cherries harvested by selective method, and this is in agreement with previous findings (Mohammedsani, 2017; Tsagaye *et al.*, 2014). Thus, harvesting methods affect the total raw quality of unwashed coffee beans whereas the drying structures do not.

4.3.9. The Total Cup Quality of Unwashed Coffee

The total cup quality of unwashed coffee is resulted from the contribution of each parameters of cup quality such as acidity, body, cup cleanness and flavor. The interaction of the harvesting methods and the drying structures showed significance effect ($P<0.0018$) on the total cup quality of unwashed coffee (Appendix Table 3). Similarly, the main effect of both of the factors showed similar significance effect ($P<0.0001$) on the total cup quality of unwashed coffee. Strip harvesting with both bare ground and cemented floor drying resulted in the similar lower mean (39.0) value whereas the similar higher mean (51.0) value for the total cup quality is recorded when selectively picked cherries dried on cemented floor, mesh wire bed and bamboo mat bed (Table 5).The higher mean (49.75) value for the total cup quality is resulted from the selectively picked cherries than strip harvested cherries due to the increased values of each cup quality

parameters in selectively picked cherries (Table 6). This is in agreement with the previous findings of other researchers that reported higher mean (45.0) value of total cup quality resulted from the selectively picked cherries than strip harvested cherries (Abadiga, 2010; Mohammedsani, 2017). Regarding to the drying structures, similar with the current study finding (49.5), Tsegaye and his colleagues reported that drying coffee cherries on the bamboo mat bed resulted in highest mean (49.33) value of the total cup quality (Tsagaye *et al.,* 2014).

4.3.10. The Overall Quality of Unwashed Coffee

The overall quality of unwashed coffee is based on the evaluation of the beans total raw physical quality attributes and total cup quality of the coffee. The combination of harvesting methods and drying structures (treatment combinations) showed no significant effect ($P>0.05$) on the overall quality of unwashed coffee (Appendix Table 3). However, the main effect of the harvesting methods and the drying structures significantly affected the overall quality of unwashed coffee at ($P<0.0001$) and ($P<0.05$) level of significance respectively. Selective picking and strip harvesting resulted in the higher mean (87.5) and lower (72.0) value for the overall quality of unwashed coffee (Table 6). The highest mean (82.5) value and the lowest mean (74.8) value for the overall quality of unwashed coffee are observed when the cherries dried on the bamboo mat bed and bare ground respectively.

The coffee with the value more than 81% is classified as specialty yet with different grade profile whereas the coffee valued less than or equal to 80% is grouped in to different commercial quality description with different grade (ECX, 2018). Hence, selective picking and strip harvesting with 87.5 and 72.0 values for the overall coffee quality is classified the coffee under specialty quality description with the second and the third commercial grade respectively. Similarly, the lowest (74.8) and the highest (82.5) value of the overall quality with bare ground and bamboo mat bed

classified the coffee under the third commercial grade and the second grade with specialty quality description respectively. The higher mean (87.5) value for the overall coffee quality of selectively picked cherries in the current study is in disagreement with previous finding which reported the higher mean value of 80.0 for selectively picked cherries (Abadiga, 2010; Mohammedsani, 2017). Regarding to the drying structures, similar to the result of the current study (82.5) the higher value (86.0) for the overall quality of unwashed coffee reported by drying the cherries on the bamboo mat bed (Tsagaye *et al.,* 2014).

The findings of current study revealed that harvesting coffee by stripping method and drying on the bare ground consequently leads to 28% and 25% loss in the overall quality of unwashed coffee respectively. This is due to the off-flavor, unpleasant odor, increased amount of both primary and secondary defects with strip harvested and bare ground dried cherries. Hence, harvesting method affect the overall coffee quality through its effect on the flavor, body, acidity and secondary defects; whereas the drying structures especially bare ground contributes by affecting flavor, odor, body, acidity and primary defects of the coffee (Appendix Table 3).

4.3.11. Grade of Unwashed Coffee

Coffee grading is based on its overall quality rather than the individual parameters of physical quality attributes and sensory quality values. The interaction effect of the treatments (combination of harvesting methods and drying structures) showed no significant ($P>0.05$) effect; whereas the main effect of the harvesting methods ($P<0.0001$) and the drying structures ($P<0.05$) significantly influenced the grade of unwashed coffee (Appendix Table 3). Better grade (grade 2) is observed from selective picking than strip harvesting (grade 3) (Table 6). Regarding to the drying structures, coffee with better grade is obtained when the cherries are dried on bamboo mat bed or mesh wire bed than bare ground or cemented floor. Hence, coffee with better

grade can be obtained from selectively picked cherries and drying on the bamboo mat or mesh wire bed. Mohammedsani (2017) reported that strip harvest resulted in coffee with fifth rank while selective picking produced the second ranked product which is similar with the current finding.

Table 6 The main effect of harvesting methods and drying structures on the unwashed coffee overall qualities and grade expressed as mean percentage

Treatments	Total raw value (40%)	Total cup value (60%)	Overall value (100%)	Rank or grade 1 up to 9
Harvesting methods				
Selective picking	37.75a	49.75a	87.50a	1.75b
Strip harvesting	30.92b	40.7b	71.7 b	3.4167a
LSD (0.05)	**1.793**	**0.9179**	**2.0142**	**0.3533**
CV	**6.034**	**2.34**	**2.9**	**15.8**
Drying structures				
Bare ground	32.3a	42.50c	74.8c	3.3333a
Cemented floor	32.5a	47.0b	79.5b	2.6667b
Mesh wire bed	33.0a	48.0b	81.5ba	2.1667c
Bamboo mat bed	33.0a	49.50a	82.5a	2.1667c
LSD (0.05)	**Ns**	**1.3**	**2.85**	**0.45**
CV	**6.034**	**2.3**	**2.9**	**15.8**

LSD = Least Significant Differences

NB: The means with the same letter in the columns are not significantly different

4.3.12. The Relationship between the Quality Parameters of Unwashed Coffee

Majority of unwashed coffee quality parameters showed strong positive correlations. However, the odor and the detection for the primary defects are not correlated with all other parameters of both raw and cup quality of the coffee (Appendix Table 4). All the parameters of coffee cup qualities are strongly positively correlated with each other, and with the values for the detection of secondary defects. For instance flavor is strongly positively correlated with acidity ($r^2 = 0.82$), body ($r^2 = 0.85$) and secondary defects ($r^2 = 0.84$) of unwashed coffee.

Total cup quality is strongly positively correlated ($r^2 = 0.99$) with total raw bean quality. Statistically, the rank of unwashed coffee is strongly negatively correlated ($r^2 = -0.96$) with its overall quality but logically this shows positive relationships between the rank and the overall values because lower natural number and higher overall values is better rank or grade.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

In *Kercha* district, both strip harvesting and selective picking methods of coffee harvesting are commonly practiced as combination in which selective picking precedes strip harvesting during the harvesting season. More than 50 percent of the farmers in the district harvest their coffee at inappropriate maturity stage which affects not only the quality aspects of the harvested produces but also the productivity of the mother tree during the next production season. As fruit maturity stage during harvest and harvesting cycles indirectly indicate the type of employed coffee harvesting methods, it can be concluded that harvesting method is amongst the major postharvest problems of unwashed coffee in the district.

Since majority of the farmers harvest coffee in *kircho* that has no effect on the coffee quality, harvesting materials are not amongst the major postharvest management problem affecting unwashed coffee quality. In the district, both males and females are involved in coffee harvesting without traditional gender discrimination whereas sorting is the postharvest management activity which is dominated by female groups and undertaken both before and after unwashed coffee processing. As coffee harvesting peak months do not coincide with rain months, currently it can be concluded that coffee harvesting period is not amongst the major problems that affecting the quality of unwashed coffee in *Kercha* district conditions.

Bamboo mat bed which maintains and controls the inherent quality of unwashed coffee is the most important coffee drying structure at farmers' level whereas cemented floor, mesh wire bed, plastic net and polyethylene sheets are the common coffee drying structures at the level of unwashed coffee processors. Hence, unwashed coffee drying structures are not amongst the

major postharvest management problems that affecting the coffee quality in the district. However, since dry cherries are completely packed into polyethylene sack which is not recommended, packing material is one of the major postharvest management problems that affecting the quality of unwashed coffee both at the levels of farmers and processors. The storage conditions and facilities at both stakeholders are amongst the postharvest management practices that affecting the coffee quality though the storage duration is not. Unwashed coffee quality inspection during the primary quality analysis is based on the coffee beans moisture level test and the visual assessment of different defects in the beans whereas during the secondary quality analysis both raw beans and cup quality analysis are imperative.

Coffee harvesting method and drying structures affect the quality of unwashed coffee by affecting each quality parameters including: odor, defects amount, acidity, body, cup cleanness and flavor of the coffee. Selective picking of only red ripe coffee cherries and drying the cherries on the bamboo mat bed or mesh wires bed results in top quality of unwashed coffee. However, strip harvesting of the cherries and drying on bare ground or cemented floor consequences in 60 percent loss in unwashed coffee cup flavor; 40 percent loss both in the cup acidity and body. It can be concluded that harvesting methods affect the quality of unwashed coffee through its effect on the flavor, body, acidity and secondary defects whereas the drying structures especially bare ground contributes by affecting flavor, odor, body, acidity and primary defects of the coffee. In addition, harvesting method and drying structures significantly affect the grade of unwashed coffee by affecting its overall quality.

5.2. Recommendations

Awareness creation for the farmers on the coffee quality control through providing extension services like training is mandatory because only less than half percent of the farmers in the district practicing selective picking of only red ripe cherries at appropriate maturity stage. The supply of the recommended coffee storage materials like jute sack should be ensured by concerned body especially it is better if the government ensured the provision of the material in the district.

There should be improvement on the storage conditions and facilities of unwashed coffee both at farmers' and processors' level. It is better if the stakeholders use a separate store room of well aerated and ventilated room to control coffee quality. In the district, the improvement in the supply of bamboo mat which maintains and controls the inherent quality of unwashed coffee should be emphasized by the concerned body. Selective picking of only red ripe cherries and drying on the mesh wire bed or bamboo mat bed is compulsory to control inherent quality of the coffee.

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7. APPENDICES

7.1. Tables

Appendix Table 1 Standard quality parameters of unwashed coffee with respective values

ECX COFFEE CONTRACTS

2.2 **Grading Factors for Unwashed Commercial Coffee**

RAW VALUE 40%					
Defects (30%)				Odor (10%)	
Primary (count) (15%)	Point	Secondary (Weight) (15%)	Point	Quality	Point
<5	15	<5%	15	Clean	10
6-10	12	<10%	12	F. clean	8
11-15	9	<15%	9	Trace	6
16-20	6	<20%	6	Light	4
21-25	3	<25%	3	Moderate	2
>25	1.5	>25%	1.5	Strong	0

CUP VALUE (60%)							
Cup Cleanness 15%		Acidity 15%		Body 15%		Flavour 15%	
Quality	Point	Quality	Point	Quality	Point	Quality	Point
Clean	15	Pointed	15	Full	15	Good	15
F. clean	12	M.pointed	12	M. full	12	F. good	12
1 cup defect	9	Medium	9	Medium	9	Average	9
2 cup defect	6	Light	6	Light	6	Fair	6
3 cup defect	3	Lacking/Dull	3	Thin	3	Commonish	3
>3 cup defect	0	Not Detected	0	N.D	0	N.D	0

Appendix Table 2 the recorded values of each quality parameter of each observation of each the treatment

No.	Rep	HM	DS	Treatment	code	Odor	PD	SD	Acidity	Body	CC	Flavor	TRV	TCV	OAV	Rank
1	1	1	1	T1	11	8	15	6	9	9	15	6	29	39	68	4
2	1	2	1	T2	21	8	15	12	12	9	15	9	35	45	80	3
3	1	2	2	T3	22	10	15	15	12	12	15	12	40	51	91	1
4	1	1	2	T4	12	10	15	9	9	9	15	9	34	42	76	3
5	1	1	3	T5	13	10	15	9	9	9	15	9	34	42	76	3
6	1	2	3	T6	23	10	15	15	12	12	15	12	40	51	91	1
7	1	2	4	T7	24	10	15	12	12	12	15	12	37	51	88	2
8	1	1	4	T8	14	10	15	9	9	9	15	6	34	39	73	3
9	2	1	1	T1	11	10	15	6	9	9	15	6	31	39	70	4
10	2	2	1	T2	21	8	15	12	12	9	15	9	35	45	80	3
11	2	2	2	T3	22	10	15	15	12	12	15	12	40	51	91	1
12	2	1	2	T4	12	10	12	6	12	9	15	9	28	45	73	3
13	2	1	3	T5	13	10	15	3	9	9	15	6	28	39	67	4
14	2	2	3	T6	23	10	15	15	12	12	15	12	40	51	91	1
15	2	2	4	T7	24	10	15	12	12	12	15	12	37	51	88	2
16	2	1	4	T8	14	10	15	3	9	9	15	6	28	39	67	4
17	3	1	1	T1	11	8	15	6	9	9	15	6	29	39	68	4
18	3	2	1	T2	21	8	15	12	12	12	15	9	35	48	83	2
19	3	2	2	T3	22	10	15	12	12	12	15	12	37	51	88	2
20	3	1	2	T4	12	10	12	9	12	9	15	9	31	45	76	3
21	3	1	3	T5	13	10	15	6	9	9	15	9	31	42	73	3
22	3	2	3	T6	23	10	15	15	12	12	15	12	40	51	91	1
23	3	2	4	T7	24	10	15	12	12	12	15	12	37	51	88	2
24	3	1	4	T8	14	10	15	9	9	9	15	6	34	39	73	3

HM= harvesting method, DS= drying structures, PD= primary defect, SD= secondary defects, CC= cup cleanness, OVA=overall value

Appendix Table 3 the P values of the parameters of unwashed coffee quality as resulted from ANOVA

Treatments	Odor	Primary defects	secondary defects	Acidity	Body	Flavor	Total raw value	Total cup value	Overall value	Grade /rank
HMs	0.3322^{ns}	0.0628^{ns}	$<0.0001^{**}$	$< 0.0001^{**}$	$<0.0001^{**}$	$<0.0001^{**}$	$<0.0001^{**}$	$<0.0001^{**}$	$<0.0001^{**}$	$< 0.0001^{**}$
DSs	$<0.0001^{**}$	0.0266^{*}	0.2573^{ns}	0.0266^{*}	0.0266^{*}	$<0.0001^{**}$	0.0791^{ns}	$<0.0001^{**}$	0.0002^{**}	0.0004^{**}
HM *DS	0.4182^{ns}	0.0266^{*}	0.2985^{ns}	0.0266^{*}	0.0266^{*}	0.0018^{**}	0.2908^{ns}	$<0.0018^{**}$	0.1223^{ns}	0.1546^{ns}

P = 0.05 level of significance, * = significant, ** = highly significant, ns= not significant

HMs = harvesting methods, DSs = drying structures, HM *DS = the interaction of harvesting methods with the drying structures

NB: Since all the treatments resulted in 15 % out of 15 % score/ value for the cup cleanness, ANOVA revealed no result for the cup cleanness.

Appendix Table 4 The correlation of each parameters of unwashed coffee quality

	Odor	PD	SD	Acidity	Body	Flavor	TRV	TCV	OAV	Rank
Odor	**1.000**									
PD	-0.155	**1.000**								
SD	0.055	0.201	**1.000**							
Acidity	-0.017	-0.255	0.768**	**1.000**						
Body	0.225	0.255	0.791**	0.714**	**1.000**					
Flavor	0.305	0.031	0.836**	0.815**	0.850**	**1.000**				
TRV	0.285	0.120	0.850**	0.806**	0.940**	0.978**	**1.000**			
TCV	0.209	0.015	0.861**	0.897**	0.913**	0.971**	0.985**	**1.000**		
OAV	0.222	0.175	0.949**	0.820**	0.910**	0.949**	0.969**	0.966**	**1.000**	
Rank	-0.305	-0.121	-0.923**	-0.747**	-0.882**	-0.898**	-0.926**	-0.912**	-0.960**	**1.000**

**. Correlation is highly significant at the 0.01 level (2-tailed). PD = primary defects, SD= secondary defects, TRV= Total raw values, TCV= total cup value, OAV= overall value

Appendix illustration 1 Unwashed coffee sample preparation for quality evaluation

Appendix illustration 2 Coffee harvesting methods in *Kercha* district

Appendix Illustrations 3 dry coffee cherries packing and storage in *kercha* district

7.3. Descriptions of the Technical Terms and Sample Questionnaires

Appendix Description 1 Definitions of the technical terms and their implications

Coffee liquor acidity is the sensation of dryness that the coffee produces under the edges of your tongue and on the back of your palate. The role that acidity plays in coffee is not unlike its role as related to the flavor of wine. It provides a sharp, bright, vibrant quality. Without sufficient acidity, the coffee will tend to taste flat. Acidity should not be confused with sour, which is an unpleasant, negative flavor characteristic (CLU, 2007).

Body of coffee liquor refers to the feeling that the coffee has in your mouth. It is the viscosity, heaviness, thickness, or richness that is perceived on the tongue. Typically, Indonesian coffees possess greater body than South and Central American coffees. Coffees with a heavier body will maintain more of their flavor when diluted with milk (CLU, 2007).

Cup cleanness: it indicates that tasting liquor cup should be free from any defects such as, cosmetics, chemicals, musty, earthy, foul, urea, etc. If all the tasted five cups detected no any cup defect, the cup quality regarded as clean whereas if only one cup out of the five detected the defect, there is fair clean cup (ECX, 2018).

Odor of coffee beans refers to the quality of the coffee beans that stimulates the olfactory organs up on smelling. It is distinctive smell of raw coffee beans as a sensation resulted from the adequate chemical stimulation of the olfactory organs. Its quality described as clean, fair clean, trace, light, moderate and strong (ECX, 2018).

Primary defects: these are visually detected defects in the raw beans such as full black beans, full sour beans, fungus developed beans, severely insect damaged beans, foreign materials, pods/ husk, etc. this is measured by physical count of the number of the defects in the beans (ECX, 2018).

Secondary defects are visually detected defects in the raw coffee beans such as immature beans, withered beans, starved beans, partially broken beans, partially sour beans, slightly insect damaged beans, shell and soiled beans. It measured as the weight ratio of the defects to the amount of the sample taken to test (ECX, 2018).

Screen 14 % refers to the amount of raw coffee beans which passed or percolated down through the sieve screen should be less than 14 % to check the size uniformity of the beans in order to ensure its uniform roasting (ECX, 2018).

Coffee cherries is red ripened (matured) coffee fruit

Coffee berries is immature coffee fruits

Kircho : A basket made from the woven bamboo mat that used for harvesting coffee.

Appendix Description 2 Sample questionnaires for the respondents

Part I: For coffee farmers

A. Demographic information

1.1. Name of farmer _____date _____Kebele/PA _____

1.2. Sex 1) Female 2) Male

1.3. Age 1) 18-33 2) 34-47 3) 48-63

1.4. Family size 1. >4 family member or 2. <4 family member

1.5. Educational status 1) Illiterate 2) Grade 1-4 3) Grade 5-8 4) High school/preparatory 5) college/university

B. Coffee harvesting practices information

1. Did you ever harvest your own coffee? 1) Yes 2) no
2. If YES for question #1, how do you know that your coffee fruit is ready for harvest? 1) Color change 2) Counting the days after flowering 3) Counting the days after fruit set 4) Other, specify_____
3. In what month your coffee flowers? (circle appropriate month)

Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug

4. In which months do you harvest coffee? (circle appropriate months)

Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug

5. What is the peak time of coffee harvesting? (In months) _____
6. How do you know this peak-harvesting month? _____

7. At what time of a day do you harvest your coffee? 1) In early morning before 4:00 am local time 2) In late morning from 4:00-6:00 am local time 3) In early afternoon before 9:00pm local time 4) In late afternoon from 9:00 – 12:00 pm local time 5) Throughout the day without time range consideration
8. If you consider the harvesting time range of day, why do you prefer that time range?

   1) Labor availability 2) no rain 3) no dew 4) other, specify_____

9. Is there any rainy time coincides with coffee harvesting time of the day? 1) yes 2) No
10. If your answer is YES for question #9, when it rains in a day? 1) in morning 2) in afternoon 3) throughout the day 4) other, specify_____
11. If your answer is yes for question # 9, how could you escape the problem?
12. Do you have time constraint during peak coffee harvesting period? 1) No 2) Yes
13. If your answer is Yes for question # 7, how do you escape the constraint?_____
14. Who often harvest your coffee? 1) Own family 2) Daily laborer 3) both
15. Who often harvest your coffee? 1) Males 2) Females 3) both involve equally 4) other,___
16. Do you have challenge of labor shortage in coffee harvesting? 1) Yes 2) No
17. If your answer is Yes for question # 16, what measure do you take to avoid the problems
18. At which fruit maturity stage do you harvest your coffee? 1) Full red ripe stage 2) Majority red ripe 3) Green mature stage 4) Majority green mature 5) Black over ripe stage 6) Other, specify_____
19. How do you harvest your coffee? 1) Selective hand picking only ripe red cherries 2) Stripping red ripe, under ripe and over ripe cherries together 3) Collecting from the ground 4) other, specify_____

20. Why do you prefer this harvesting method than others? 1) It saves the harvesting time 2) It saves harvesting labor 3) Coffee will be sold with high price 4) other, specify_____

21. In how many frequencies do you harvest your coffee in one harvesting season? 1) Once a week 2) once per two weeks 3) once a month 4) every time when cherries ripe/red 5) once per harvesting season 6) others (specify) _____

22. Why do you harvest in such frequency? 1) To save time 2) To save labor 3) Coffee fruit does not ripe at the same time 4) other, specify_____

23. During harvesting your coffee, to get high price of your coffee for what you give more attention? 1) Harvesting high amount of coffee 2) Harvesting high quality coffee 3) Harvesting without considering quantity and quality 4) other, specify_____

24. Do you give attention for your coffee quality? 1) Yes 2) No

25. If your answer is YES for question # 23, at what time do you give more attention for coffee quality? 1) Before harvesting 2) During harvesting 3) After harvesting 4) I give attention at any time 5) Other, specify_____

26. If your answer is YES for question # 23, what measures do you take to control the quality of your coffee?

27. Do you harvest the coffee for washed and unwashed process in similar manner? 1) Yes 2) No

28. If you answer is NO for question # 23, how do you harvest the coffee for dry process?

1) Selective hand picking only red ripe cherries 2) Stripping red ripe, under ripe and over ripe cherries together 3) Collecting from the ground 4) other, specify_____

29. What containers/materials do you need to harvest your coffee? 1) Jute sack

2) Polyethylene sack, 3) Hard polyethylene bucket 4) metal bucket 5)other specify_____

C. Post-harvest practice information

30. On what do you dry your coffee? 1) On bare ground 2) On cemented ground 3) On mesh wire bed 4) On bamboo mat bed 5) Other, specify_____

31. Why do you prefer this drying structure than others?(more than one alternatives are possible)

1) It is low cost 2) I can easily prepare it 3) Coffee will be sold at high price 4) coffee dried in short time 5) Other, specify_____

32. How long it takes to dry your coffee completely? 1) < 1 week 2) from 1-2 weeks

3) > 2weeks 4) Other, specify_____

33. Do you consider moisture content of your coffee when drying it? 1) Yes 2) No

34. How could you know that your coffee is dried enough? 1) Using machine 2) crushing between teeth 3) by using its sound 4) counting the days that the coffee put sun

5) Other, specify_____

35. Have you seen mold development on your coffee when drying? 1) Yes 2) No

36. Where do you sell your coffee? 1) At primary level coffee transaction center 2) At local market 3) At unwashed coffee processing factory 4) Other, specify_____

37. Why do you sell your coffee in that place? 1) Government's rule and regulation on coffee marketing 2) Many buyers at the market 3) Closeness to dry coffee processing 4) Other, specify_____

38. Do you sort the coffee you harvest for dry processing? 1) Yes 2) No)

39. If your answer is Yes for question #38, when do you sort your coffee?

1) Before drying 2) After drying 3) Both before drying and after drying 4) Other, specify_____

40. From which equal amount of fresh cherry or dried cherry of coffee do you get more price?

1) Fresh cherries 2) dried cherries

41. Do you consider layer thickness of your coffee when drying? 1) Yes 2) No

42. If your answer is Yes for question # 41, what layer thickness do you need to dry your coffee properly? 1) < 5cm 2) 5cm-10cm 3) >10cm

43. Do you stir your coffee when drying it? 1) Yes 2) No

44. If your answer is yes for question #43, how often do you stir your coffee when drying?

1) Once per day 2) twice per day 3) three times per day 4) once per week 5) twice per week 6) Other, specify_____

45. Did you get training on coffee quality control in the last 12 months? 1) Yes 2) No

46. What packing material do you use for storing coffee after dried?

1) Jute sack 2) Polyethylene sack, 3) Hard plastic bucket 4) metal bucket 5) other specify_____

47. Do you store your coffee before sell? 1) Yes 2) No

48. If your answer Yes for question # 47, where did you store it? 1) In residence home

2) In warehouse 3) anywhere free space is available 4) other, specify_____

49. For how long do you store your coffee after dried? 1) Sale immediately after drying

2) After 1-4 month storage 3) 4-6 month storage 4) 6-12 months storage 5) other, specify_____

50. Why do you prefer selling in such time? 1) I have no store house 2) coffee price will increase 3) rule and regulation of government 4) Other, specify_____

51. After a long period of storage is it the weight loss of your coffee 1) Yes 2) No

52. If Q # 51 Yes, out of one quantal of your coffee how many kg losses in average? _____

53. What is the price per Kg of dried coffee at market in 2017/18? Min ____ birr, Max _____birr aver____ birr.

54. Does your coffee quality is preferred by your customers? 1) Yes 2) No

55. What do you think the reason for Q # 54 above? _____

56. How can you know high quality coffee for good price? _____

57. Have you seen mold development on your coffee when storing it? 1) Yes 2) No

58. If Yes for question # 57, is there any effect of that mold development on the price of your coffee? 1) Yes 2) No

59. If your answer is Yes for question #58, how do you sell your coffee with mold developed?

1) I could not sell at any price at all 2) I can sell at low price 3) I can sell at high price

4) Other, specify_____

60. If your answer is Yes for question #58, do you remove the mold from your coffee?

1) Yes 2) No

61. If your answer is Yes for question #61, How do you remove the mold?

62. To whom you are selling your dried coffee this year?

1. Farmers Cooperative (name_____) 2) To dry coffee Processors 3) Local retailer 4) To the middle men/ agent 5) Other specify_____

63. Did you get any extension service on the coffee quality control in the past three years? 1. Yes 2. No

64. If Q # 63 Yes, what type of coffee quality extension service did you get?(more than one alternatives are possible) 1) Training 2) Advices 3) materials 4) Other, specify

65. If Q # 63 Yes, who provide this extension service? 1) Coffee and tea development and marketing authority office 2) DAs 3) Model farmers 4) research center 5) Other, specify_____

66. Which specific type of advice/ training the stakeholders give to you every year? (more than one alternatives are possible) 1) coffee Quality control 2) Field management 3) Disease management 4) Other, specify _____

67. What are the problems currently facing you in coffee production and marketing?

68. What do you think should be done to solve them in the future?

Part II: For dry coffee processors/traders

A. Demographic information

1.1. Full name of the processor/trader_____

City/town/district_____ date_____

1.2. Sex 1) Female 2) Male

1.3. Age 1) 18-33 2) 34-47 3) 48-63

1.4. Family size 1) >4 family member or 2) <4 family member

1.5. Educational status 1) Illiterate 2) Grade 1-4 3)

Grade 5-8 4) High school/preparatory 5) college/university

B. Post-harvest practice

1. When do you start the business of coffee processing and supplying (Year)?

2. From where and whom you purchase a coffee?

3. What is your average purchase price for one kilo of unprocessed dry coffee in this year 2017/18? _____ birr

4. After you hulled coffee, how do you control your coffee quality?

5. Do you mix product of different quality before/after hulled and why?

6. How do you identify the quality of the product you purchase and product from another source whether adulterated or not?

7. Do you purchase both fresh red cherries and dried parchment coffee?

8. If you buy red cherries, how and where you dry it?

9. How do you control coffee quality during purchasing, processing, drying, packaging, storage, transporting and marketing?

10. How much is the average of your purchase of dry parchment coffee per week?_____kg

11. Most of the time your dry coffee was getting which grade and why?_____/

because_____

12. How is the price of different grade of coffee at ECX transaction center in the past three years?

1) Increasing 2) decreasing 3) usually up and down 4) Other, specify_____

13. What are the constraints in coffee quality and marketing?

14. For the last 12 months, did you take any training about coffee quality? 1. Yes 2. No.

15. Do you get extension service regularly and timely? 1 Yes 2. No

16. Do you have market advisor? 1. Yes 2. No

17. Do you have moisture tester to estimate the level of dryness (moisture content) before storage?

1. Yes 2. No

18. Do you have separate coffee store? 1. Yes 2. No

19. What type of coffee store floor do you use? 1) Concrete 2) Wooden bed 3)Paved ground

20. Do you store coffee before and after the process and why

21. How long do you keep your coffee in store before taking to central market? 1) Sale immediately after processing 2) After 1-4 month storage 3) 4-6 month storage 4) 6-12 months storage 5) other, specify_____

22. Why do you prefer such storage time? 1) I have no store house 2) coffee price will increase 3) rule and regulation of government 4) Other, specify_____

23. Is there any weight loss during storage of your coffee? 1) Yes 2) No 3) Neither increase nor decrease

24. If Yes for Q#23 above, what amount kilogram of weight loss in average?_____

25. If No for Q#23 above, what amount kilogram of weight increases in average?_____

26. How do you decide coffee price? 1) Based on Radio announcement 2) Own judgment 3) Following leading buyer's Price 4) Based on exporters in formation 5) Other, specify

26. While you buy coffee, how could you check its quality? 1) Through observation and Judgment 2) No means of checking 3) others, specify _____

27. What criteria are used to check coffee quality at the district level?

28. What are the criteria used at central market for giving grades for coffee?

Part III: Ethiopia commodity exchange (ECX) particulars

Name: _____ Position: _____

Date of interview _____ address _____

1. How your organization currently controls coffee quality?
2. What is your main function as coffees stack holder organization?
3. What is the current method of coffee quality assessment?

4. What are the quality parameters of coffee grading?
5. Is it similar assessment parameters of quality both for washed and unwashed coffee? __
6. If No for Q#5 above, what parameters do you need to check quality of unwashed coffee?
7. How and where coffee grade performed?
8. What criteria should fulfill for export standard of coffee?
9. What do you do when the coffee evaluated by your organization fail to fit the criteria?
10. To what coffee inherent quality categories and brand name your coffee belongs
11. How do you know the geographical regions/areas where the coffee was grown?
12. What is the quality trend of coffee comes from kercha district
13. What are the main problems of coffee quality which comes from Kercha district?
14. To what inherent quality category and brand name does the coffee comes from kercha district belongs?
15. What is the grade of coffee comes from Kercha for the last three years?
16. How do you decide coffee price?

BIOGRAPHICAL SKETCH

The author, Daniel Duba was born from his father Duba Bulula and his mother Marta Ababa in Sokora Diriba of Goro Dola District on April 25, 1990. He attained his elementary and junior school education at Sokora Diriba Primary and Wadera Junior School respectively whereas He continued his high school and preparatory education at Negele Senior Secondary and Preparatory School in Guji zone of Oromia regional state. Afterward, He joined Dilla University, Department of Horticulture in 2008 and graduated with BSc degree in Horticulture Science on July 3, 2010. Soon after graduation, he was employed in Guji Zone Agriculture and Rural Development Office as 'Coffee Quality Control and Marketing expert' and served there for four years from 2011 - 2014. After that, He got the opportunity to join Bule Hora University where He served as Graduate assistant –II for two years. Then after, He joined Hawassa University School of Graduate Studies in Horticulture in October, 2016. Now a time He is waiting for successful completion of his MSc. degree in Horticulture in 2018. The author is a single for meanwhile.