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INFLUENCE OF SUN DRYING METHODS AND LAYER THICKNESS ON QUALITY OF MIDLAND ARABICA COFFEE VARIETIES AT GOMMA-II, SOUTHEWEST ETHIOPIA

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ABSTRACT

Coffee is the backbone of Ethiopia's economy, contributing the highest of all exports revenues. Despite the economic importance, productivity and quality of the crop is very low. In Ethiopia it is processed in two different methods on different drying materials across locations. However, lack of information on post harvest processing and drying on quality necessitates a comprehensive study.Therefore, this experiment was carried out to determine the effects of altitude, sun drying methods, variety and cherry drying layer thickness on quality of coffee at Gomma-II. Accordingly, on-farm processing experiments were conducted at state owned coffee farms under Limmu Coffee Plantation Development Enterprise (LCPDE) from September up to December, 2010. The experiment was laid out in 3x3x4 Split-Split-plot design arranged in CRD with three replications. The three factors comprise three drying materials: bricks floor, raised beds with bamboo mats and mesh wires assigned to the main-plots. Three coffee varieties: 744, 74110 and 744+74110 assigned to sub-plots and four levels of cherry layer thicknesses: 20; 30; 40kg/m^2 (uniformly spread) and the farmers' conventional practices (40kg/m^2) as sub-sub plot treatments. Analysis was computed to estimate the average response suitable for particular Gomma-II. Similarly, cupping was done by three cuppers at (OCFCU) coffee cupping laboratory in March, 2011. The data were computed by using list significant differences (LSD) procedures of SAS version 9.2. As a result, the interaction effects were highly significant ($P \leq 0.01$) for total coffee quality and significant variations were observed ($P \leq 0.05$) for drying period, total raw quality, total cup quality and coffee grades. The finding revealed that; processing coffee on raised beds using appropriate layer thickness loads of 20 to 30kg/m^2 at mid altitudes produce quality coffee identified as total quality scores ranging 80-89.99 points and can attain "Specialty Grade 1 and 2" classification profiled under Grade 2.While, the conventional systems produce low quality coffee identified as commercial grade classifications profiled under Grade 3 to 6. Hence, using appropriate dry processing approaches, it is possible to produce specialty coffee.

Keywords: Sun-drying, Layer thickness, On-farm processing, total quality and Specialty coffee

INTRODUCTION

Coffee *(Coffea arabica L)* is the backbone of Ethiopia's economy, contributing the highest of all exports revenues. Ethiopia is the original home of *Coffea arabica*, and thus, possesses the largest diversity in coffee genetic resources and Africa's leading producer and exporter of Arabica coffee (Mayne *et al*., 2002; Girma, 2003). The country largely depends on coffee as a major earner of the economy. It has accounted on average for about 5% of Gross Domestic Product (GDP), 10% of Total Agricultural Production and 41% of total export earnings for the past few years (Worako *et al*., 2008).

Over 25% of the populations of Ethiopia, representing 15 million people, are dependent on coffee for their livelihoods (Oxfam, 2002; IMF, 2006).

It is produced in many places of Ethiopia that range in altitude from 550 to 2750 meters above sea level. The bulk of *Coffea arabica* is produced in the Eastern, Southern and Western parts of Ethiopia, with altitudes ranging from 1300 to 1800 m.a.s.l. (Aklilu and Ludi, 2010). The total area coverage of coffee is estimated to be around 800,000 hectare which accounts for 3.14% of the country's total area under crop cultivation of which about 95% is produced by 1.2 million small scale farmers. At present, Ethiopia exports 170,000 tons and the domestic consumption is estimated to be about 50% of the total production (Esayas, 2009; Aklilu and Ludi, 2010). Although, Ethiopia is known to be the first in Africa in terms of coffee production and eighth major supplier of the global market, its share accounts for only 3% of the global coffee trade.

Methods of coffee processing in Ethiopia are sun-drying of unpulped cherries and wet processing, of which sun drying is preferred by farmers. From the total coffee production of Ethiopia, the highest proportion accounts for dry processed coffee. Washed coffee accounts for 29% while sun-dried accounts for 71% of the processed coffee (Musebe *et al.*, 2007). Similarly, Ethiopia exports about 65-70% natural or sun-dried coffee and 30-35 % wet-processed coffee (Russell, 2008).Quality is the most important parameter in the world coffee trade. It is estimated that the quality of coffee is determined by 40% in the field, 40% at post-harvest primary processing and 20% at secondary processing and handling including storage (Musebe *et al.*, 2007). This underscores the importance of primary processing in enhancing the quality and value of coffee. Quality losses occur due to poor post-harvest on-farm processing, including poor storage infrastructure and contamination with other products. The bulk of Ethiopian coffee exports are low grade coffee, 3rd or 4th quality grade classification (Desse, 2008).

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

The problem of post-harvest processing and handling as one of the main contributing factor in the area resulted in poor quality. Farmers dry their coffee using different approaches. About 48% of producers spread their coffee on the ground, about 49.5% dry on raised drying beds using either bamboo mats or wire meshes and only 2.5% dry on cemented/bricks floors (Musebe *et al.*, 2007). Furthermore, farmers' cultural practices on post-harvest operations, such as mixed drying and undesirable layer thickness of coffee upon drying and heaping of coffee before drying favoured development of fungus and bacteria and cause quality deterioration.

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

MATERIALS AND METHODS

Description of the study areas

Field processing experiments were carried out at state owned Limmu Coffee Plantation Enterprise (LCPE) at Gomma-II in Jimma zone in Gomma Worda. According to Limmu Coffee Plantation Enterprise (LCPE) the farm represent midland coffee growing areas with geographical location of $7^0 55^1$N and $36^0 37^1$E having an altitude of 1650m.a.s.l and average maximum and minimum temperature of 25^0C and 12^0C respectively with an annual average rain-fall 1400 mm.

Experimental factors

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

Experimental design

The experiments were laid out in 3x3x4 Split-Split-plot design arranged in CRD with three replications at three locations (Poduska, 2008). The three drying materials were assigned as main plots, three coffee varieties as sub plots and four cherry layer thicknesses as sub-sub plot treatments. Randomizations were held separately and independently for each of the replications where the treatments are assigned completely at random as described by (Gomez and Gomez, 1984).

Data collection and quality analysis

Clean coffee bean sample of 500g was taken from each treatment combination based on sampling procedure set by Ethiopian standard (ESBN 8.001) and (MoA), which is on the basis of drawing 3kg per 10 tons. Representative samples were drawn and laboratory size samples were prepared from bulk samples. The quality analysis was carried out from March 11 to April 18, 2011. Green bean physical and cup quality characteristics were evaluated by three Q certified professional coffee tasters. Data for the physical and organoleptic analysis were taken from 350g green coffee sample with optimum moisture content (11.5%). These include: days to drying(days), total raw quality (Primary defect (count) (15%), Secondary defect (weight) (15%) and Odor (10%)), total cup quality (Cup cleanness (15%), Acidity (15%), Body (15%), and flavor (15%)), total quality (Sum total of both physical and organoleptic quality: 90-100=Outstanding specialties, 85- 89.99= Excellent Specialties, 80-84.99=Very Good specialties and <80.0= Below Specialty coffee quality (Not Specialty) and grading (Grade 1=91-100; Grade 2=81-90; Grade 3=71-80; Grade 4=63-70; Grade 5=58- 62; Grade 6=50-57; Grade 7=40-49; Grade 8=31-39; Grade 9=20-30; Under Grade=15-19) [12]. Finally, quality analysis was conducted at Oromia Coffee Farmers Cooperative Union (OCFCU) coffee cupping laboratory in Addis Ababa.

Statistical analysis

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

RESULTS AND DISCUSSION

Days to drying

Data presented in Table 1 shows highly significant *($P \leq 0.01$)* variations among drying materials with respect to days to drying. Coffee cherries dried on raised beds covered with mesh wire took longer time of drying (18.33 days).While, cherries dried on bricks terraces and bamboo mats recorded statistically similar and the shortest drying period (16.14 and 16.58 days) respectively. This could be due to the fact that the area is medium altitude prevailing favorable temperature which allows more condensation on bricks terraces and raised bed covered with bamboo mats than mesh wire. The result agrees with the findings reported by FAO (2010b) in good drying conditions terraces perform well than tables because of higher temperatures, whereas, in periods of rain the table is superior because open lower surface prevents condensation and allows drying to continue slowly. Similarly, the result also inline with the findings of Beza (2011) who reported that dry processed coffee on mesh wire took much longer time and coffee drying on bamboo and cement floor dried earlier. The finding of the present work supported by Lower et al. (2007) who pointed out that coffee beans may require more days to dry depending on the methods of drying and the density at which the beans are dried.

Table 1. Effects of drying material on days to drying of cherries at Gomma-II

Drying material	Drying period (days)
Bricks	16.14[b]
Bamboo mats	16.58[b]
Mesh wire	18.33[a]
LSD (P≤0.01)	0.526
CV (%)	8.85

Similarly, the influence of cherry layer thickness on drying period at Gomma-II has highly significant *(P≤0.01)* differences among levels of cherries loads (Table 2).The earliest time of drying (15.11days) were recorded on thin layer thickness level with loading rate of 20kg/m^2.On the other hand, the thick layer thickness levels of the conventional system with the same loads of coffee 40kg/m^2 took statistically similar and the longest time of drying (18.33 and 18.37days) respectively. The possible reasons for this could be the weather condition and the fact that the coffee cheery dried with its thick levels maintains its moisture because of low air movement within masses of cherries may require longer time to dry. Hence, as drying density levels increased, there was a linear increase in drying time and vice versa. The above finding also supports with the findings given by Lower *et al* (2007) the coffee beans may require more days to dry depending on the methods of drying and the density at which the beans are dried. Similar results were reported by Solomon and Behailu (2006) and ICO (2010) who stated that in Arabica coffee for a given thickness layer, the length of the drying process depends mainly on weather conditions and degree of moisture content and size of the berries.

Table 2. Influence of layer thicknesses on days to drying of cherries at Gomma-II

Levels of layer thicknesses (kg/m^2)	Drying period (days)
20	15.11[c]
30	16.93[b]
40	18.37 [a]
40 (Conventional)	18.33[a]
LSD (P≤0.01)	0.830
CV (%)	8.85

Total raw quality

Regarding the physical quality, the result indicates the characteristics detected for quality assessment of coffee. The analysis of variance in the three way interaction effects among drying materials, variety and layer thicknesses shows the presence of significant *(P≤0.05)* variations on the total raw quality of coffee at Gomma-II (Table 3). Coffee variety 74110 dried on mesh wire using density level of 20 kg/m^2 recorded the highest mean raw quality value (38) points. On the contrary, coffee variety 74110 dried on bricks floor scored the lowest mean raw quality value (16.83) points. These could be due to the combined effects of three way interactions specifically bricks in particular and raised beds with thick layers favored for mould development that interns blotchy and foxy nature of beans. Furthermore, sever insect attack was observed while quality assessment of coffee from Gomma-II. Hence, inappropriate processing and pest attacks increase the degree of defect counts and affects both color and odor of the beans. Similar results were reported by Selmar et al. (2006); FAO (2010b) and

ICO (2010) indicated that in processing Arabica coffee drying tables covered in mesh or mats are used and simplify protection of the crop from re-wetting. Furthermore, the finding of the present work supported by Negussie et al. (2009) and Subedi (2010) who pointed out that properly processed coffee is free off- flavour and very few defective beans.Coffee dried on bricks floor in contact with soil becomes dirty and blotchy resulting into dull aroma and earthy flavor in coffee beverage.

Table 3. Interaction effects among drying materials, variety and layer thicknesses on total raw quality of unwashed Arabica coffee at Gomma-II

Drying material	**Variety**	**Layer Thickness (kg/m^2)**	**Total raw quality**
Bricks	744	20	26.50^{ef}
Bricks	744	30	21.17^{g}
Bricks	744	40	19.17^{gh}
Bricks	744	40(conv.)	18.17^{gh}
Bricks	74110	20	18.83^{gh}
Bricks	74110	30	18.17^{gh}
Bricks	74110	40	16.83^{h}
Bricks	74110	40(conv.)	19.17^{gh}
Bricks	744+74110	20	26.33^{def}
Bricks	744+74110	30	20.83^{g}
Bricks	744+74110	40	19.17^{gh}
Bricks	744+74110	40(conv.)	19.50^{gh}
Bamboo mats	744	20	28.00^{def}
Bamboo mats	744	30	26.50^{def}
Bamboo mats	744	40	29.00^{de}
Bamboo mats	744	40(conv.)	25.83^{ef}
Bamboo mats	74110	20	34.00^{b}
Bamboo mats	74110	30	26.50^{def}
Bamboo mats	74110	40	29.00^{de}
Bamboo mats	74110	40(conv.)	25.17^{f}
Bamboo mats	744+74110	20	33.00^{bc}
Bamboo mats	744+74110	30	27.00^{def}
Bamboo mats	744+74110	40	25.83^{ef}
Bamboo mats	744+74110	40(conv.)	25.83^{ef}
Mesh wire	744	20	35.00^{ab}
Mesh wire	744	30	29.00^{de}
Mesh wire	744	40	27.00^{def}
Mesh wire	744	40(conv.)	24.83^{f}
Mesh wire	74110	20	38.00^{a}
Mesh wire	74110	30	29.00^{de}
Mesh wire	74110	40	29.50^{cd}
Mesh wire	74110	40(conv.)	25.83^{ef}
Mesh wire	744+74110	20	35.67^{ab}
Mesh wire	744+74110	30	35.00^{ab}
Mesh wire	744+74110	40	26.50^{def}
Mesh wire	744+74110	40(conv.)	26.50^{def}
LSD ($P \leq 0.05$)			3.588
CV (%)			8.38

Total cup quality

The sensory evaluation revealed significant *($P \leq 0.05$)* variations between the sun drying methods and the coffee varieties on total cup quality at Gomma-II. Coffee variety 74110 dried on bamboo mats scored the highest mean total cup quality value (47.00) point's evaluated organoleptic analysis. On the other hand, the mean smallest total cup value (43.00) point was recorded from coffee variety 74110 dried on bricks terraces (Table 4). This result possibly found due to the combined effect of inherent variability that exists in the respective varieties and the drying methods used in coffee processing. The drying process on raised beds covered with bamboo mats and mesh wire having better air movement maintained the inherent quality attributes of the variety. The result agrees with the findings of Musebe et al. (2007) and ICO (2010) who confirmed improved sun-drying wherein coffee is dried on raised drying beds is advocated for improved quality. Further more, this result is in line with Anwar (2010) who reported that coffee drying by using raised bed with mesh wire, wooden and bamboo mats have better quality. Similar findings were reported by Yigzaw (2005) who reported that the presence of genetic variability among Ethiopian coffee selections for green bean physical characteristics and cup quality attributes. This statement also supports the findings of Subedi (2010) pertaining to bean size play an important role in roasting processes because many consumers associate bean size with quality. However, large beans do not necessarily taste better than smaller one. Furthermore, the finding was in agreement with the finding of Mekonnen (2009) and Negussie et al. (2009) where sun dried coffee variety dried on raised beds following appropriate management had a good physical and over all cup quality are concerned.

Table 4. Interaction effects between drying materials and variety on total cup quality of dry processed coffee at Gomma-II

Drying material	Variety	Total cup quality
Bricks	744	44.00^{cd}
Bricks	74110	43.00^{d}
Bricks	744 +74110	43.75^{cd}
Bamboo mats	744	44.75^{bc}
Bamboo mats	74110	47.00^{a}
Bamboo mats	744 +74110	45.75^{ab}
Mesh wire	744	44.75^{bc}
Mesh wire	74110	45.00^{bc}
Mesh wire	744 +74110	44.00^{cd}
LSD ($P \leq 0.05$)		*1.572*
CV(%)		*4.30*

Similarly, the overall test of the brew was influenced by the combined effect of sun- drying methods and density levels of cherries while processing. Statistically significant ($P \leq 0.05$) variations were observed between the interaction effects of the two factors on total cup quality of coffee at Gomma-II. Coffee dried on raised beds covered with mesh wire using the layer thicknesses levels of with the loads of 20kg/m^2 recorded the highest sensory evaluation mean value (48.33) points. On the other hand, statistically similar and the smallest mean total cup quality values (41.00 and 40.00) points were recorded from coffee dried both on bricks terraces and raised beds with mesh wire using the conventional practices and density levels of 40kg/m^2 respectively (Table 5).This quality variation could possibly be occurred due to the combined effects of the drying methods and the density levels of cherries while processing. Using raised beds covered with mesh wire and bamboo mats having better air movement and thin levels of cherries density revealed better cup quality. Whereas, the thick layered cherries exposed to re-wetting problem in the conventional system favored the risk of mould development, black bean formation and fermentation in the pulp that could affect total cup quality. The finding agrees with the reports of Endale (2008) and FAO (2010b) found that coffee carefully prepared and handled with a better management free from undesirable elements to have a better flavour cup quality. Solomon and Behailu (2006) also confirmed that higher heaps result admixture of under dried and over dried beans. Consequently, the coffee is heaped unevenly yielding inferior cup taste or quality. Antonym and Surip (2010) also confirmed that the natural coffee processing can produce high quality coffee and creates a highly preferred coffee compared to full washed coffee and wet-hulled indicating that processing does have an identifiable influence on cup taste.

Table 5. The effects of interaction between drying methods and density levels on total cup quality of unwashed coffee at Gomma-II

Drying Materials	Layer thickness(kg/m^2)	Total cup quality
Bricks	20	46.33^{bc}
Bricks	30	43.67^{ef}
Bricks	40	43.33^{f}
Bricks	40(conv.)	41.00^{g}
Bamboo mats	20	47.67^{ab}
Bamboo mats	30	46.00^{bc}
Bamboo mats	40	45.67^{cd}
Bamboo mats	40(conv.)	44.00d^{ef}
Mesh wire	20	48.33^{a}
Mesh wire	30	45.33^{cde}
Mesh wire	40	44.66^{cdef}
Mesh wire	40(conv.)	40.00^{g}
LSD ($P\leq0.05$)		1.816
CV(%)		4.30

Total Coffee Quality

With regards to the total coffee quality, the interaction effects among sun drying methods, varieties and cherries layer thicknesses revealed significant *($P\leq0.05$)* variations on total quality of Arabica coffee at Gomma-II. The variety 74110 dried on raised bed with mesh wire using the layer thickness loads of 20kg/m^2 recorded the highest mean total quality points (88.00) detected to excellent specialty taste received a "Specialty Grade 1" classification. Also, the variety 74110 and 744 dried on raised beds covered with bamboo mats using loads of 20kg/m^2 and the variety 744 and the combination of the two varieties (744+74110) in equal ratios dried on mesh wire using loads of 20 and 30kg/m^2 recorded the mean total coffee quality values (84.00;84.00;82.00 and 81.00) points respectively. Furthermore, the combination of the two varieties(744 +74110) dried on mesh wire using the density levels of 30kg/m^2 scored the mean total quality point (80.00) detected to very good specialty taste received a "Specialty Grade 2" classification. On the other hand, the lowest mean total quality point (58.83) was recorded from coffee variety 74110 dried on bricks using layer thickness loads of 40kg/m^2 (Table 6). Whereas, the rest of the interaction effects of the treatment combinations are identified as commercial grade classifications with specified categories of grade ranges (71-80; 63-70 and 58-62) total quality points profiled under grade 3, 4 and 5 respectively. This result possibly found due to the combined effect of all the three factors: sun-drying methods, the inherent variability in the respective varieties and the influence of cherries density levels per unit area. The variety 74110 and the combinations of the two varieties (7411+74110) dried on raised beds using thin layer thickness loads of 20kg/m^2 produces very good specialty taste received a "Specialty Grade 2" classification. Generally, the three way interaction effects determine the over all quality of coffee at Gomma-II. The result agrees with the findings of Appropedia (2010) who pointed out that a good quality finished dry processed product can only be obtained through the application of appropriate and scientifically tested practices and proper management. Similarly, this result is in line with Mekonnen (2009) and Anwar (2010) who reported that coffee drying by using raised beds covered with mesh wire and bamboo mats following appropriate management have better quality as far as their total physical and cup quality are concerned. The present finding also supports Antonym and Surip (2010) who pointed out that if consistent quality control is applied to dry processing the resulting coffee is highly preferred by the specialty coffee industry.

Table 6. Interaction effects among drying materials, variety and layer thicknesses on total quality of dry processed Arabica coffee at Gomma-II

Drying material	Variety	Layer thickness (kg/m^2)	Total quality
Bricks	744	20	73.50^{cdef}
Bricks	744	30	65.17^{jklm}
Bricks	744	40	63.17^{lmn}
Bricks	744	40(conv.)	59.17^{no}
Bricks	74110	20	64.83^{jklm}
Bricks	74110	30	61.17^{mno}
Bricks	74110	40	58.83^{o}
Bricks	74110	40(conv.)	59.17^{no}
Bricks	744+74110	20	72.33^{cdefg}
Bricks	744+74110	30	63.83^{klm}
Bricks	744+74110	40	63.17^{lmn}
Bricks	744+74110	40(conv.)	61.50^{mno}
Bamboo mats	744	20	73.00^{cdef}
Bamboo mats	744	30	71.50^{cdefgh}
Bamboo mats	744	40	74.00^{cde}
Bamboo mats	744	40(conv.)	69.83^{fghi}
Bamboo mats	74110	20	84.00^{ab}
Bamboo mats	74110	30	72.50^{cdefgh}
Bamboo mats	74110	40	75.00^{c}
Bamboo mats	74110	40(conv.)	70.16^{efgh}
Bamboo mats	744+74110	20	81.00^{b}
Bamboo mats	744+74110	30	74.00^{cde}
Bamboo mats	744+74110	40	70.83^{defgh}
Bamboo mats	744+74110	40(conv.)	68.83^{ghij}
Mesh wire	744	20	84.00^{ab}
Mesh wire	744	30	75.00^{c}
Mesh wire	744	40	72.00^{cdefg}
Mesh wire	744	40(conv.)	63.83^{klm}
Mesh wire	74110	20	88.00^{a}
Mesh wire	74110	30	74.00^{cde}
Mesh wire	74110	40	74.50^{cd}
Mesh wire	74110	40(conv.)	65.83^{ijkl}
Mesh wire	744+74110	20	82.00^{b}
Mesh wire	744+74110	30	80.00^{b}
Mesh wire	744+74110	40	70.50^{defgh}
Mesh wire	744+74110	40(conv.)	67.50^{hijk}
LSD ($P \leq 0.05$)			4.067
CV (%)			3.51

Coffee grading

The two way interaction effects between sun drying methods and coffee variety shows highly significant differences at *($P \leq 0.01$)* on grades of unwashed Arabica Coffee at Gomma-II. The Variety 74110 dried on bamboo mats recorded the best mean coffee grading score (2.92) points. Whereas, the lowest grading score (5.00) is recorded from similar variety (74110) dried on bricks (Table 7). The probable reason could be due to the variability between the combined effect of the processing technologies and the inherent quality characteristics of coffee varieties. The farmers' conventional system induces intermixing and re-wetting of cherries to be favored for mould development and quality deterioration. Whereas, drying tables covered with bamboo mats and mesh wire simplifies protection of the crop from re-wetting because the open lower surface prevents condensation. JARC (1996) confirmed that coffee variety 74110 is highly suitable at medium altitudes and it has commercially good accepted quality. This result is in line with Anwar (2010) and Beza (2011) who reported sun dried coffee variety dried on raised beds with mesh wire following appropriate management had a good physical and over all cup quality are concerned. Further more dry processed variety 74110 dried on mesh wire, and bamboo mats was profiled under Grade 2. While, the conventional way of coffee preparation samples took lower Grade 4 and 3 respectively. Similar results were reported by Subedi (2010) who indicated that the coffee dried on bricks floor in contact with soil has also a great influence on their aroma and flavor performance of produce quality.

Table 7. Interaction effects between drying materials and variety on grades of dry processed coffee at Gomma-II.

Drying material	Variety	Grades
Bricks	744	4.08[b]
Bricks	74110	5.00[a]
Bricks	744 +74110	4.17[b]
Bamboo mats	744	3.25[c]
Bamboo mats	74110	2.92[d]
Bamboo mats	744 +74110	3.17[cd]
Mesh wire	744	3.08[cd]
Mesh wire	74110	3.00[cd]
Mesh wire	744 +74110	3.08[cd]
LSD (P≤0.01)		*0.319*
CV (%)		*11.78*

Similarly, the interaction effects between sun drying methods, and cherry layer thicknesses shows significant differences at *(P≤0.05)* on grades of unwashed Arabica coffee at Gomma-II. Coffee dried on mesh wires and bamboo mats using cherries density levels of 20kg/m^2 recorded statistically similar and the highest coffee grade (2.11and 2.44) points respectively. Whereas, the lowest coffee grade score (5.11) was recorded from the coffee dried on bricks with loads of 40kg/m^2 treated as the conventional practices (Table 8). The probable reason for coffee grade variations could be due to the combined effect of the processing methods and the levels of cherry layer thicknesses while processing determine the quality grades of coffee. The farmers' conventional system induces intermixing and re-wetting of cherries to be favored for mould development and quality deterioration. On the other hand, drying tables covered with bamboo mats and mesh wire prevent the crop from re-wetting and have ambient air movements in two sides to encourage uniform drying. Similar results were reported by Bhawan and East Arjun (2006) and ICO (2010) indicated that the thinner the layer the earlier to drying and producing high quality coffee, for coffee drying under good ambient conditions. Moreover, the structures of the drying facilities have also a great influence on their performance of coffee quality grades. This result is also in line with Anwar (2010) who reported that dry processing method was affected by processing approaches. Further more, the finding was in agreement with the finding of Mekonnen (2009) where sun dried coffee variety dried on raised beds with mesh wire following appropriate management had a good physical and over all cup quality are concerned. Negussie et al. (2009) confirmed that if properly processed, all coffees produced can attain higher grades.

Table 8.The interaction effects between drying materials and density levels on grades of unwashed coffee at Gomma-II

Drying materials	Layer thickness(kg/m^2)	Coffee grades
Bricks	20	3.33^{e}
Bricks	30	4.44^{bc}
Bricks	40	4.78^{ab}
Bricks	40(conv.)	5.11^{a}
Bamboo mats	20	2.44^{g}
Bamboo mats	30	3.11^{ef}
Bamboo mats	40	3.11^{ef}
Bamboo mats	40(conv.)	3.78^{d}
Mesh wire	20	2.11^{g}
Mesh wire	30	2.88^{f}
Mesh wire	40	3.11^{ef}
Mesh wire	40(conv.)	4.11^{cd}
LSD ($P \leq 0.05$)		0.392
CV (%)		11.78

CONCLUSION

Although Ethiopia is known to be the first in Africa in terms of coffee production and eighth major supplier of the global market, its share accounts for only 3% of the global coffee trade. This calls for transition to more dynamic and innovative quality approaches.

At Gomma-II, the finding shows that cherries dried on bricks and bamboo mats dried earlier .While, coffee dried on mesh wire took much longer time with more percentage moisture content. The result also indicates coffee loads with thin layer thicknesses dried earlier and took short drying period. Whereas, the thick layers treated as the conventional system took longer drying period. Hence, appropriate dry processing activities begins by harvesting red ripe cherries and drying of coffee on bricks floor and bamboo mats with thin layer thicknesses took shorter drying period. However, coffee dried on raised beds covered by mesh wire with thick density levels of 40kg/m^2 took longer drying period.

On the basis of the raw quality analysis, there were variations on three way interaction effects. Coffee dried on mesh wire with thin layer thickness scored the highest raw quality mean values. On the contrary, coffee dried on bricks with thick layer thickness earned the lowest raw quality score. Hence, drying coffee on mesh wire and bamboo mats with thin layer thicknesses earned better raw quality attributes because of ample air movement and fast dehydration to minimize further fermentation and mould development on drying. With regards to cup quality attributes, small sized beans (74110) dried on bamboo mats with thin layer thickness (20kg/m^2) scored the highest mean total cup quality value. On the other hand, similar coffee variety dried on bricks terraces with the layer thickness loads of 40kg/m^2 treated as farmers' practices produced the lowest total cup quality value. Hence, at Gomma-II, dry processing of coffee using raised beds covered with bamboo mats with thin layer thicknesses produce better cup quality coffee as compared to mesh wires and bricks. Whereas, coffee dried on bricks with thick layer thickness produces poor cup quality coffee.

The findings also show variations on total coffee quality. Coffee variety 74110 dried on mesh wire with layer thickness level of 20 kg/m^2 scored the highest total quality value received a "Specialty Grade 1" classification profiled under grade 2. Similarly, coffee dried on bamboo mats with layer thickness loads of 20kg/m^2 and mesh with density levels of 20 and 30kg/m^2 recorded (>80.00) total quality points respectively received a "Specialty Grade 2" classification profiled under Grade 2. Hence, processing coffee with sun drying methods using raised beds covered with bamboo mats and mesh wire using appropriate layer thicknesses (3 to 5 cm) in deep, which is equivalent to 20 to 30kg/m^2 of fresh cherry produce specialty coffee grades.

Finally, on the basis of specialty coffee market demand and from economic point of view, drying coffee both on raised beds covered with bamboo mats and mesh wire with the density levels of 20 to 30kg/m^2 produce high quality coffee and recommended for midland areas in Jimma zone like that of Gomma-II areas. On the contrary, quality deterioration associated with dry processing in conventional system lowers the quality standards of coffee and is strongly discouraged under smallholders' farmers' condition. Consequently, based on the interest of consumers and specialty market producing high quality coffee earns more income for coffee farmers in particular and the coffee industry as a whole. Thus, special attention should be given to dry processing approach through refinement of sun drying methods on post-harvest processing practices for quality improvement of dry processed Arabica coffee.

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