FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Effect of processing and drying methods on biochemical composition of coffee (Coffea arabica L.) varieties in Jimma Zone, Southwestern Ethiopia

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Abstract: There has been minimal research on the effect of location, processing, and drying methods on the biochemical composition of Ethiopian coffee varieties, despite extensive research on the biochemical compositions of green bean and roasted coffee and their effects on cup quality. The current study aims to close this gap in the literature. Its goal is to determine the impact of coffee processing (fully washed and semi-washed) and drying procedures (natural sun, artificial and solar tunnel) on the biochemical compositions of coffee varieties (741, 74110, and 7440) at Gomma-I and Limmu Kossa, southwest Ethiopia. The biochemical compositions were quantified using a Fourier Transform-NIR spectrometer prediction model. The results showed in both locations, the interaction impact of varieties, processing, and drying methods considerably influenced most of the biochemical contents of the green bean. At both locations, all varieties processed by full wash and dried by artificial produced higher caffeine content. At Gomma-I, variety 741 processed by semi-wash and dried by artificial method produced higher TCGA value than the other treatment while the finding at Limmu Kossa was a bit complex. At Gomma-I, Arabica coffee varieties (7440 and 74110) dried by artificial produced more sucrose content regardless of the processing methods used. In general, greater mean

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PUBLIC INTEREST STATEMENT

Ethiopia is the world’s fifth-largest producer and eighth exporter of Arabica coffee varieties. Coffee is a major export for the country, accounting for more than 34% of its foreign exchange revenues. Green bean coffee chemical components are thought to be precursors of coffee cup quality characteristics including fragrance, flavour, acidity, etc. However, chemical components found in coffee are determined by a combination of genetic, environmental, processing, and drying techniques used. Despite substantial research on the biochemical compositions of green bean and roasted coffee beans and their influence on cup quality, nothing has been done to examine the effects of location, processing, and drying techniques on the biochemical make-up of Ethiopian coffee varieties. Therefore, the current initiative aims to close these research gaps.
values of caffeine, TCGA, trigonelline, and sucrose content of green beans were recorded from artificial. Hence, the effect of varieties, growing conditions, processing and drying methods on the biochemical compositions of coffee is highly complex and location specific recommendation is required to get better quality.

**Subjects:** Biodiversity & Conservation; Food Additives & Ingredients; Food Chemistry  
**Keywords:** caffeine; chlorogenic-acid; demucilager; solar tunnel; sucrose; trigonelline

1. Introduction

Coffee is the world's most widely traded raw resource (Davis et al., 2012), and it has also become the most important export product for the countries that grow it. Ethiopia is the world's fifth largest producer and exporter of coffee (ICO, 2018). Coffee is extremely important to Ethiopia's economy, accounting for more than 34% of the country's foreign exchange revenues in 2018/19 (USDA, 2018). On relatively small parcels of land, over four million small-scale farmers in Ethiopia produce over 95 percent of Ethiopian coffee (CSA, 2013; USDA, 2013). Coffee directly or indirectly supports the livelihoods of 15 million people, the majority of whom are smallholder farmers (CSA, 2013).

Quality is currently becoming a more important and vital aspect in the coffee industry's economy, determining pricing structure, product demand (acceptability), and reputation, as well as the country's coffee industry's existence and the economy or profitability of coffee farming as a business. Physical quality, sensory cup quality, and inherent chemical contents of the green bean generated all contribute to coffee quality. Green coffee beans are rich in a variety of chemical components (Kathurima et al., 2010). These chemical components are thought to be precursors of coffee cup quality characteristics such as fragrance and flavor (Joët et al., 2010). Bitterness is caused by biochemical substances in coffee such as caffeine and chlorogenic acid (Joët et al., 2010). Sucrose makes up more than 90% of the entire low-molecular-carbohydrate content of green coffee beans (Bytof & Peter, 2005; Knopp et al., 2006), and it also functions as an aroma precursor, producing a number of chemicals (such as furans, aldehydes, and carboxylic acids) that influence the flavor and scent of the beverage (Farah, 2006). Trigonelline is known to contribute indirectly to the synthesis of ideal taste components during coffee roasting (Mengistu et al., 2020).

Chemical components found in coffee are determined by a combination of genetic, environmental, and technical variables (Farah, 2006). Several studies have found that growth conditions, processing procedures, and drying techniques have a significant impact on coffee biochemical makeup and final cup quality (Gichimu et al., 2014; Wang & Lim, 2012). According to another study, the processing method used affects the chemical content of raw coffee beans (Bytof & Peter, 2005). Post-harvest processing alters the chemical makeup of coffee seeds, notably water-soluble components such sugars, caffeine, trigonelline, and chlorogenic acids (Duarte et al., 2010).

In Ethiopia, coffee is processed using both dry and wet processes, with dry processing being the most popular among small-scale producers. As a result, dry coffee processing accounts for 70% of overall production, while washed coffee preparation accounts for 30% (ECX, 2008). Limmu Coffee Plantation Private Limited Company, for example, in the study region, uses wet processing methods for coffee processing, which are known as full-washed and semi-washed processes. Ethiopia has recently introduced a semi-washed coffee processing technology, in which the fermentation process is omitted, and the mucilage is removed with a mechanical de-mucilage equipment. This technique has the advantage of minimizing water usage as well as the risk of surface water contamination (Willem, 2007) and saving time (Steiman, 2011). Furthermore, when compared to the full-washed procedure, this method is known to reduce the danger of over-fermentation and quality issues in the final coffee product.
Other factors impacting coffee quality and biochemical contents include coffee drying systems. Coffee is dried mostly by the sun in Ethiopia, and in large commercial plantations, both the sun and artificial drying methods are used. On the other hand, sun drying has a variety of disadvantages, counting the potential for food contamination, a wide range of drying times, a high labor requirement, and a reliance on weather conditions. On the other hand, artificial drying method is faster but it demands high initial cost for the machine as well as for fuel (Sontakke & Salve, 2015). A solar tunnel dryer has recently been introduced and installed in various coffee-growing districts of Ethiopia, in response to the shortage of fuel. The solar tunnel dryer is thought to assist improve dried coffee quality (color, texture, and flavor), reduce postharvest loss and product contamination (by insects, microorganisms, and mycotoxin), and cut drying time in half (Tomar et al., 2017). According to another analysis, solar dryers are frequently a less expensive and easy-to-manage solution that can potentially lessen environmental impact and eliminate the need for fuel (Sontakke & Salve, 2015).

As a result, in addition to the artificial hot air dryer, the solar tunnel dryer has been recently introduced and is now being used by most commercial coffee farms, including those in the study area, without any controlled studies to confirm its effectiveness in drying, impact on quality, or biochemical compositions. Thus, it is critical to comprehend the effects of unique location, processing, and drying procedures on the biochemical contents of coffee varietals. Although some studies have looked at the biochemical compositions of green bean and the impact of roasted coffee beans on cup quality (Gure et al., 2014; Kathurima et al., 2010; Tessema et al., 2011), there are few studies that look at the impact of location, processing, and drying methods on Ethiopian coffee cultivars’ biochemical composition.

As a result, it is necessary to evaluate the impact of various processing methods as well as the comparative performance of existing and newly introduced drying systems under different coffee growing environments (Gomma I and Limmu Kossa, representing mid to highland area, respectively) and involving different coffee varieties. There has been minimal research on the effect of location, processing, and drying methods on the biochemical composition of Ethiopian coffee kinds, despite extensive research on the biochemical compositions of green bean and roasted coffee beans and their effects on cup quality. As a result, the current work aims to fill this knowledge vacuum. To this end, the present study was aimed at quantifying the influence of coffee processing and drying methods on biochemical compositions (caffeine, chlorogenic acid, trigonelline and sucrose) of coffee varieties at Gomma-I and Limmu Kossa, southwest Ethiopia.

2. Materials and methods

2.1. Description of the study area

The experiment was conducted at the Horizon Coffee Plantation Private Limited Company (PLC), Limmu coffee farms, located at Gomma I and Limmu Kossa of Jimma Zone, Oromia Regional State, Southwest Ethiopia. Gomma I is located in Gomma district while Limmu Kossa coffee farm is located in Limmu Genet district of Jimma Zone. Gomma I farm is located at 397 km to the Southwest of Addis Ababa. It has an area of 1,230.2 km² (123,020 ha) of which 8% is highland, 88% is medium highland and 4% is lowland. The annual rainfall varies between 800 and 2000 mm. The mean minimum and maximum temperatures of the Gomma district are 7–12°C and 25–30°C, respectively. It has an elevation ranging from 1400 to 2270 m.a.s.l (Gomma Agricultural and Rural Development Office’s report). At Gomma I farm, the specific study site is located at 1500 meters above sea level, representing the mid altitude coffee production environment (Table 1). Limmu Kossa farm is located 421 km southwest of Addis Ababa. It has an area of 1,230.2 km² (123,020 ha), of which 25% is highland, 63% medium highland and 12% lowland. The annual rainfall varies between 1200 and 1850 mm. The mean minimum and maximum temperatures of the district are 7°C (12°C) and 25°C (30°C), respectively. Its elevation ranges from 1400 to 2470 m.a.s.l. (Limmu Genet Agricultural and Rural Development Office’s report). At Limmu Kossa farm, the specific study site is located at 1850 m above sea level, representing the highland coffee production environment (Table 1). A detailed description of the study areas is given by Figure 1 and is given in Table 1.
2.2. Experimental treatment and design

The experiment consisted of three factors evaluated at two locations (Gomma I and Limmu Kossa). Three Coffee Berry Disease (CBD) resistant Arabica coffee varieties, namely 741, 7440, and 74110, were considered in this study. These varieties were purposely selected due to their high yielding capacity, resistance to coffee berry disease (Getu et al., 2015) and being the most widely grown in the study areas (Coffee production Development Enterpries, 2005). These varieties were selected with the intention of representing open, intermediate, and compact canopies as well as small, medium, and large bean sizes of coffee (Bossolasco, 2009; Coffee Production Manual, 2017).

Table 1. Detail explanation of the study areas

| No. | Descriptions                              | Gomma-1          | Limmu Kossa        |
|-----|-------------------------------------------|------------------|--------------------|
| 1   | Distance from Jimma (Km)                  | 60               | 53                 |
| 2   | Geographical location                      | 7°59′N36°42′E    | 7°50′N36°53′E      |
| 3   | Altitudinal range of the farm (m.a.s.l)   | 1430–1800        | 1600–1950          |
| 4   | Altitude of the specific site (masl)       | 1,500            | 1,850              |
| 5   | Maximum temperature (°C)                  | 28               | 26                 |
| 6   | Minimum temperature (°C)                  | 14               | 12                 |
| 7   | Rain fall (mm)                            | 1,143            | 1,680              |
| 8   | Coffee plantation area (ha)               | 1,233            | 1,340              |

Source: LCPE, (2010) Unpublished annual report
The spacing used by the company for the selected coffee varieties such as 741, 7440, and 74110 was 2 × 2 meter, 2 × 1.8 meter, and 2 × 1.75 meter, respectively (Coffee Production Manual, 2017). Two processing methods (fully washed and semi washed) as well as three drying methods (sun, solar tunnel, and artificial) were used for the study. The treatments were arranged as a factorial experiment using Randomized Complete Block Design (RCBD) with three replications.

### 2.3. Sample preparation

For the purpose of uniform processing, red and ripe coffee cherries were selectively harvested at each study site independently during the peak harvesting period. A selective handpicking method was used for the harvesting of the cherries from the three different improved coffee varieties. At each study site, a total of 54 samples (3 varieties × 2 processing methods × 3 drying methods × 3 replications) were collected for the purpose of biochemical analysis of green coffee beans. Red ripe coffee cherries were pulped individually using a coffee pulper machine (Aagaard pregrader, McKinnon, Brazil) for the fully washed coffee processing procedure. The parchment coffee was separated from the pulp and immersed underwater to separate the floaters shortly after pulping. The heavier parchment coffee was then left to ferment for 24 hours in the fermentation tank. Following the breakdown of the slippery mucilage, the parchment coffee was washed and steeped in clean water for another 24 hours. The parchment coffee was washed with pure water after the mucilage was removed and pre-dried or partially sun-dried.

In semi-washed processing method, the skin of the fresh cherry was physically removed by a pulper machine with addition of water, as with full-wash processing. The muclilage was then removed immediately after pulping using a demucilager machine (Muclilage remover, Pinhalense, Brazil). To remove any leftover muclilage, the parchment coffee was washed with pure water. Finally, the parchment coffee was washed with clean water and subjected to pre-drying on wire-mashed raised beds.

Pre-drying parchment coffee on wire-mesh raised beds for two days reduced the moisture content of the parchment coffee beans from around 60% to 30%, which was measured using coffee bean moisture meters (GMK-307C). Following that, at each study site, 54 samples with a moisture content of around 30% were dried until a moisture level of 11.5% was achieved using each drying method (sun, solar tunnel, and artificial). The ambient air temperature at the research area ranged from 21°C to 23°C, the room temperature for the solar tunnel drier was 35°C to 40°C, and the artificial dryer was 90°C.

### 2.4. Biochemical composition analysis

The major biochemical compositions (caffeine, chlorogenic acid, trigonelline and sucrose) were quantified using a Fourier Transform-NIR spectrometer prediction model (Tango, Brüker, Belgium). The tests were done in the coffee lab at Jimma University’s College of Agriculture and Veterinary Medicine. Green coffee samples were ground to a size smaller than 5 mm and 15 g of each sample was used for analysis to develop the prediction model. The samples were irradiated with tungsten (5 V/7 W) of near infrared light. The reflectance was detected by an Indium Gallium Arsenide diode, and the spectra were obtained within a range of 4000 to 11,500 cm⁻¹ with a spectral resolution of 8 cm⁻¹ (Figure 2). High Performance Liquid Chromatography was used to determine the reference analysis of each biochemical composition (caffeine, chlorogenic acid, trigonelline), whereas sucrose was determined using a gas chromatograph (GC-3380, Varian, USA). A flame ionization detector was used to make the detection.

Prior to model creation, it was critical to pre-process original NIR spectra to remove undesired information such as spectral noise. As the result specific pre-processing methods techniques (Derivatives and vector normalisation) were selected based on the lowest root mean square error of cross validation. Then partial Least Squares (PLS) regression analysis was used with OPUS QUANT software version 7.2 (Brüker, Belgium) to construct a linear relationship between spectral data (Figure 2) and reference/concentration data (Table 2). The coefficient of multiple determinations (R²), root mean square error of cross validation (RMSECV), and residual prediction
deviation were used to assess the predictive models’ performance (RPD). The value of RMSECV should be as low as possible for a robust model, with high $R^2$ and RPD values (Tolessa et al., 2016).

2.5. Statistical analysis

Before conducting the analysis, the collected biochemical data were checked for the assumption of Analysis of Variance (ANOVA). The data were then analyzed using SAS software version 9.3 to determine the effect of processing and drying methods on the biochemical compositions of the selected coffee varieties at the Gomma-I and Limmu Kossa coffee farms. Since the variation of error variance between the two locations was very high, the analysis was done separately for each location; a combined analysis over all locations was not done. In all analyses, the confidence level of significance was held at a 5% probability level. Significant differences between treatment means were separated using the Least Significant Difference (LSD). Since the high level interaction (Variety X Processing X Drying methods) showed significant difference for all biochemical data considered, mean separation was done only for the three way interaction.

3. Results

3.1. Analysis of variance

The results from the analysis of variance indicate that the three-way interaction of coffee varieties, processing methods, and drying methods significantly ($P < 0.05$) affected all biochemical
compositions determined (caffeine, total chlorogenic acid (TCGA), trigonelline, and sucrose) at Gomma-I. On the other hand, at Limmu Kossa, only total chlorogenic acid and sucrose were significantly ($P < 0.05$) affected by the three-way interaction of coffee varieties, processing methods, and drying methods. Caffeine content was significantly ($P < 0.05$) affected by the main effect of drying methods and the two-way interaction of processing methods and coffee varieties. The trigonelline content was significantly ($P < 0.05$) influenced only by the coffee varieties. The mean separation and interpretation of the result in this manuscript is done accordingly. Overall to dry the parchment coffee to 11.5% moisture content after pre-drying (30% moisture content), the sun drying method, the solar tunnel dryer and the artificial drying method takes 8 days, 4 days, and 30 hours, respectively.

### 3.2. Effect of processing and drying methods on biochemical composition of coffee varieties Gomma-I

The findings of the study in general indicate that coffee dried by the artificial drying method produces more caffeine content than the other two drying methods (Table 3). The result also indicated that there was significant variation among the processing methods on the content of caffeine. Except for variety 741, the other two coffee varieties produced more caffeine when processed by full washing method than the semi wash. The content of the caffeine on each coffee variety depends on the types of processing and drying methods used during postharvest handling.

| Variety | Processing method | Drying method | Caffeine | Total chlorogenic acid (TCGA) | Trigonelline | Sucrose |
|---------|-------------------|---------------|----------|-------------------------------|--------------|---------|
| 741     | Full washed       | Sun           | 1.28cde  | 5.44 cd                        | 1.21abc      | 9.96bcd |
|         |                   | Solar tunnel  | 1.36abc  | 5.20de                        | 1.12abcd     | 10.16bcd|
|         |                   | Artificial    | 1.31bcd  | 5.74ab                        | 1.22abc      | 7.92 g  |
|         | Semi washed       | Sun           | 1.22efg  | 5.07efgh                      | 0.93def      | 8.89ef  |
|         |                   | Solar tunnel  | 1.20fgh  | 5.69bc                        | 0.86 f       | 8.57fg  |
|         |                   | Artificial    | 1.43a    | 6.35a                         | 1.18abc      | 10.07bcd|
| 7440    | Full washed       | Sun           | 1.06jkl  | 5.11efg                       | 0.87ef       | 9.83 cd |
|         |                   | Solar tunnel  | 1.00 l   | 4.80hi                        | 0.84 f       | 9.59de  |
|         |                   | Artificial    | 1.35abc  | 5.41 cd                       | 1.24ab       | 10.50abc|
|         | Semi washed       | Sun           | 1.06ijkl | 5.05efgh                      | 1.10bcd      | 9.61de  |
|         |                   | Solar tunnel  | 1.03kl   | 4.46 j                        | 1.09bcde     | 9.93bcd |
|         |                   | Artificial    | 1.25def  | 5.65bc                        | 1.12abcd     | 10.55abc|
| 74110   | Full washed       | Sun           | 1.06ijkl | 4.66ij                        | 1.04bcdef    | 9.84 cd |
|         |                   | Solar tunnel  | 1.11ijk  | 4.86fgi                       | 1.32a        | 9.52de  |
|         |                   | Artificial    | 1.38ab   | 5.68bc                        | 1.21abc      | 11.30a |
|         | Semi washed       | Sun           | 1.14hij  | 5.10efg                       | 1.14abcd     | 9.56de  |
|         |                   | Solar tunnel  | 1.13hij  | 4.83ghi                       | 1.01cdef     | 9.77 cd |
|         |                   | Artificial    | 1.22efg  | 5.15def                       | 1.15abc      | 10.69ab |
| LSD (0.05%) | 0.08  | 0.30  | 0.22 | 0.81 |
| CV (%)  | 4.27  | 3.49  | 12.10 | 5.00 |

Mean values followed by the same letter with in a column are not significantly different at $P = 0.05$. 
washing and dried by the solar tunnel drying method (Table 3). However, this result was on par with variety 741 processed by the full-washed method and dried by the three drying methods, with variety 7440 processed by the full and semi-washed method and dried by the artificial drying method, and with variety 74110 processed by the full-washed and semi-washed method and dried by the three drying methods.

For sucrose, the highest mean value (11.30g/100g) was recorded for variety 74110 processed by the full-washed method and dried by the artificial drying method (Table 3). However, statistically, there were no significant variations between variety 7440 processed by the fully washed and semi-washed methods and dried by the artificial drying method, and variety 74110 processed by semi-washed and dried by the artificial drying method. On the other hand, variety 741 processed by full-washed and dried by the artificial drying method recorded the lowest mean value of 7.92g/100g compared to the other two varieties, even though the recorded mean value of all varieties included in this study was greater in the sucrose content of green coffee beans.

### 3.3. Limmu Kossa
The highest mean value of TCGA (6.02g/100g) was recorded for variety 74110, processed by semi-washed and dried by the artificial drying method (Table 4). However, this result was on par with variety 741 processed by the full-washed and semi-washed methods and dried by the sun and artificial drying methods, respectively, and also with variety 74110 processed by the full-washed and semi-washed methods and dried by both the sun and artificial and solar tunnel drying methods.

| Variety  | Processing method | Drying method | Total chlorogenic acid (TCGA) | Sucrose      |
|----------|-------------------|---------------|------------------------------|--------------|
| 741      | Full washed       | Sun           | 5.75ab                      | 9.81abcd     |
|          |                   | Solar tunnel  | 5.27bcdef                   | 9.87abcd     |
|          |                   | Artificial    | 4.93efg                     | 10.42ab      |
|          | Semi washed       | Sun           | 5.22bcdef                   | 10.35ab      |
|          |                   | Solar tunnel  | 4.86fg                      | 10.61a       |
|          |                   | Artificial    | 5.74f                       | 9.10d        |
| 7440     | Full washed       | Sun           | 4.58 g                      | 9.86abcd     |
|          |                   | Solar tunnel  | 4.81fg                      | 10.03abc     |
|          |                   | Artificial    | 4.8f                        | 10.02abc     |
|          | Semi washed       | Sun           | 5.22bcdef                   | 9.58bcd      |
|          |                   | Solar tunnel  | 5.12efg                     | 9.15d        |
|          |                   | Artificial    | 5.15abcd                    | 10.13abc     |
| 74110    | Full washed       | Sun           | 5.75ab                      | 9.34cd       |
|          |                   | Solar tunnel  | 5.14def                     | 9.80abcd     |
|          |                   | Artificial    | 5.53abcd                    | 9.89abcd     |
|          | Semi washed       | Sun           | 5.44bcde                    | 9.39 cd      |
|          |                   | Solar tunnel  | 5.69abc                     | 7.97e        |
|          |                   | Artificial    | 6.02                        | 7.88e        |
| LSD (0.05%)|                  |               | 0.54                        | 0.85         |
| CV (%)   |                   |               | 6.20                        | 5.31         |

Mean values followed by the same letter with in a column are not significantly different at \( P = 0.05 \).
methods, respectively. On the other hand, the lowest mean value (4.58g/100g) was recorded for variety 7440 processed by full-wash and dried by the sun drying method.

For sucrose, the highest mean value (10.61g/100g) was recorded for variety 741 processed by semi-washing and dried by the solar tunnel drying method (Table 4). However, statistically, there were no significant variations from variety 741 processed by full-washed and dried by the three drying methods and processed by semi-washed and dried by sun drying method and from variety 7440 processed by full-washed and dried by the three drying methods and processed by semi-washed and dried by the artificial drying method and also from variety 74110 processed by full washed and dried by solar tunnel and artificial drying methods.

The study also showed significant variation among coffee drying methods for the caffeine content of green coffee beans. The highest mean value (1.29g/100g) for caffeine content was recorded for coffee beans produced through the artificial drying method, while the lowest mean value (1.23g/100g) was registered for coffee beans dried by both the sun and solar tunnel drying methods (Table 5).

The interactive effects of variety and processing methods also significantly influenced the caffeine content of green coffee beans. The highest mean value (1.30g/100g) was recorded for variety 74110 processed by the semi-wasted method. However, there were no statistically significant differences between varieties 741 processed fully washed and 7440 and 741 processed semi-washed. On the other hand, varieties 74110 and 7440 showed a decreased caffeine content when fully washed (Table 6).

| Table 5. Influence of drying methods on caffeine content of Coffea arabica L. at Limmu Kossa |
| Drying methods | Caffeine |
| Sun | 1.23b |
| Solar tunnel | 1.23b |
| Artificial | 1.29a |
| LSD (0.05%) | 0.04 |
| CV (%) | 4.33 |

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

| Table 6. Interactive effect of variety and processing methods on caffeine content of Coffea arabica L at Limmu Kossa |
| Variety | Processing methods | Caffeine |
| 741 | Full washed | 1.27ab |
| 7440 | Full washed | 1.19c |
| 74,110 | Full washed | 1.22bc |
| 741 | Semi washed | 1.25abc |
| 7440 | Semi washed | 1.26ab |
| 74,110 | Semi washed | 1.30a |
| LSD (0.05%) | | 0.05 |
| CV (%) | | 4.33 |

Mean values followed by the same letter with in a column are not significantly different at P = 0.05.
Table 7. Effect of variety on trigonelline content of *Coffea arabica* L at Limmu Kossa

| Variety | Trigonelline |
|---------|-------------|
| 741     | 1.08ab      |
| 7440    | 1.15a       |
| 74,110  | 0.99b       |
| LSD (0.05%) | 0.10        |
| CV (%) | 13.87       |

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

Significant variations were observed among coffee varieties for the trigonelline content of green coffee beans. The highest trigonelline mean value was recorded for varieties 7440 and 741, while the lowest mean value was recorded for variety 74110 (Table 7).

4. Discussion

The current investigation found considerable differences in the biochemical contents of green coffee beans among varieties, processing methods, drying methods, and their interactions at both locations. At Gomma-I, the three-way interaction effect of variety, processing, and drying methods was significant for caffeine, total chlorogenic acid, trigonelline, and sucrose content of green coffee beans. However, at Limmu Kossa, the three-way interaction of varieties, processing, and drying methods was significant only for total chlorogenic acid and sucrose content of green coffee beans. The caffeine content was significantly influenced by interaction between variety and processing methods and main effect of drying methods. At Limmu Kossa, trigonelline content was only affected by the main effect of Arabica coffee varieties.

At both locations the study indicated that all coffee varieties processed by full wash method showed in general a greater mean value for the caffeine content of green beans compared to the other treatment combination. Some previous studies reported also higher caffeine content was registered for coffee beans processed by the full-washed method compared to coffee beans processed by the semi-washed (Duarte et al., 2010; Tolessa et al., 2019).

Regarding the drying methods, in general, all coffee varieties dried by the artificial drying method produces more caffeine than coffee varieties dried by natural sun. The high caffeine content observed for coffee beans dried by artificial drying methods may be due to the absence of direct solar radiation from the dryer, as the dryer uses electric power or other sources of power-like fuel or wood. Therefore, the artificial drying method may reduce the loss of biochemical compounds from the bean during drying time. The result is in line with the report of Sontakke and Salve (2015) who indicated that the artificial drying method maintains the quality of product by avoiding direct exposure to solar radiation.

The current study indicated that the absence of variations among the coffee varieties evaluated for the caffeine content of green coffee beans. The caffeine content of the evaluated Arabica coffee varieties ranged from 1.0% to 1.43% (Table 3). The low level variation could be associated with the limited number of Arabica coffee varieties used in this study. The result is in contrast with some previous studies (Mengistu et al., 2020; Tolessa et al., 2019) who indicated that the presence of significant variations in green bean caffeine content among different coffee genotypes. The average caffeine level of Arabica coffee has been reported to be around 1.2% in the previous studies, with a range of 0.6% to 1.9% (Belay et al., 2008; Franca et al., 2005).

The interactive effect of variety, processing, and drying methods showed significant variations in the TCGA content of green coffee beans. At Gomma I, variety 741 processed by semi-wash and dried by artificial method produced higher TCGA value than the other treatment combination (Table 3) while the finding at Limmu Kossa was a bit complex. All processing and drying methods produced statistically
higher TCGA values with different varieties at different locations (Tables 3 and 4). Moreover, regardless of the processing and drying methods used, both 741 and 74110 Arabica coffee varieties produced more TCGA value than 7440 Arabica coffee variety. The findings are consistent with prior research (Farah & Donangelo, 2006; Mengistu et al., 2020), which found that total CGA concentration in green coffee beans varies substantially depending on varieties. Furthermore, the findings are consistent with those of Sontakke and Salve (2015), who found that artificial drying preserves product quality by avoiding direct contact to solar radiation. In contrast to the present study, however, some previous studies (Duarte et al., 2010; Tolessa et al., 2019) indicated higher contents of chlorogenic acids for coffee beans processed by the full-washed method compared to the semi-washed. On the other hand, Joët et al. (2010) reported no influence of the postharvest processing method on the chlorogenic acid content of green coffee beans.

The study also demonstrated that the interactive effects of variety, processing methods, and drying methods significantly influence the trigonelline content of green coffee beans. All varieties processed either by full wash or semi-wash and dried by artificial drying method produced more trigonelline content at Goma I. In contrast to this finding, a significant variation in trigonelline content among Arabica coffee accessions was reported (Mengistu et al., 2020).

The interactive effect of variety, processing, and drying methods showed significant variations in the sucrose content of green coffee beans. At Gomma I, coffee varieties (7440 and 74110) dried by artificial drying method produced more sucrose content regardless of the processing methods employed while the result at Limmu Kossa was a bit complex. In contrast to the present study, some previous studies showed that sucrose is not significantly affected by the types of postharvest processing methods, neither for Arabica nor for Robusta coffee (Knopp et al., 2006; Leloup et al., 2005).

5. Conclusions
The study showed that the biochemical composition of Arabica coffee significantly influenced by the type of coffee varieties grown, the processing and drying methods employed and their interactions at both locations. At both locations, all varieties processed by full wash and dried by artificial dryer produced higher caffeine content. The current study indicated that the absence of variations among the coffee varieties evaluated for the caffeine content of green coffee beans. At Gomma I, variety 741 processed by semi-wash and dried by artificial method produced higher TCGA value than the other treatment while the finding at Limmu Kossa was a bit complex and requires further refining. On the other hand, at Gomma I, Arabica coffee varieties (7440 and 74110) dried by artificial dryer produced more sucrose content regardless of the processing methods used. In general, greater mean values of caffeine, TCGA, trigonelline, and sucrose content of green coffee beans were recorded from artificial dryer. Therefore, from the present study, we can conclude that the effect of coffee varieties, growing conditions, processing and drying methods on the biochemical compositions of green coffee beans is highly complex and location specific recommendation is required to get better quality.

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