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Research Article

Coffee Drying and Processing Method Influence Quality of Arabica Coffee Varieties (Coffee arabica L.) at Gomma I and Limmu Kossa, Southwest Ethiopia

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Solar tunnel drying and semiwash processing methods are popular among coffee growers in southwestern Ethiopia. However, the effect of these processing methods on coffee quality has not been studied in detail. The objective of this study was to evaluate the effect of processing and drying methods on the quality of coffee varieties at Gomma-I and Limmu Kossa areas in the 2016/2017 growing season. Two processing methods (fully washed and semiwashed) and three drying methods (solar tunnel, artificial, and natural sun) were compared using three coffee varieties (741, 7440, and 74110) to test their effect on coffee quality. Coffee beans processed by semiwash method and dried by solar tunnel produced nondefective (primary and secondary) coffee beans compared with others at both locations. Similarly, coffee beans processed by semiwashed method recorded the highest mean value for shape and make and body than wet processing method. Best coffee bean color, greenish color, was produced from coffee beans processed by the fully washed processing method. All coffee varieties processed by semiwashed method produced medium pointed acidity, the second most acceptable grade value for coffee quality for all drying methods. Coffee beans processed by the fully washed method produced more flavor than semiwash processing method. Coffee beans dried by sun and solar tunnel drying methods also produced better flavor than artificial drier. In general, all coffee varieties processed by semiwash method and dried by natural sun and solar tunnel method produced higher preliminary total quality and total specialty coffee value, graded under specialty grade Q1. Hence, coffee growers in the study area can use semiwash processing method and solar tunnel dryer as an alternative/complementary processing method since they produce better or equivalent quality product with full wash and natural sun drying method.

1. Introduction

Coffee is one of the most important cash crops for many countries across the world. The crop is produced in more than 80 countries [1], and for many developing countries, it is the most important source of foreign currency [2]. In the 2020/2021 production year, in Ethiopia, the areas covered by coffee production are estimated to be about 856,591.99 ha with a production of about 584,789.57 tons of green coffee [3]. Ethiopia possesses a diverse genetic base of Arabica coffee with considerable heterogeneity [4]. The country produces a range of distinctive Arabica coffee and has considerable potential to sell a large number of specialty coffee beans. However, many factors influence the coffee quality and hence its export potentials. Many studies indicated that coffee physical and cup quality is largely determined by genetic factor, growing condition, processing methods, and the techniques used for drying [5–9].

In Ethiopia, coffee processing is carried out by dry and wash (wet) processing methods. Washed coffee processing method has been mainly practiced by commercial coffee farms [10]. In washed coffee processing method, both natural fermentation (i.e., full washing method) and demucilager (i.e. semiwashing method) are being used to degrade and remove the slimy mucilage compound from the bean. In the case of semiwash, the fermentation step is omitted and the mucilage is removed by a demucilage machine and there is no need for any kind of fermentation before drying. This method has been reported as modern and known for its simplicity, high water use efficiency [11], reduced coffee weight loss [12], and less time requirement compared with the full-wash method [13]. Because of such an advantage, the semiwash processing method (i.e. the use of demucilager) is currently being popularized and used by small-scale coffee producers in Ethiopia. However, little information has been known about the influence of the semiwash method on preliminary quality and specialty quality of coffee in Ethiopia.

The drying process is very important for keeping the quality of coffee [14], as drying reduces the humidity content of the bean and impedes the microbial action that is responsible for spoilage during storage. In Ethiopia, smallholder coffee producers dry their coffee using the natural sun. This method of drying, however, has many limitations, including variability in drying duration, high labor demand, and dependence on weather conditions. The long rainy season prevailing in southwest Ethiopia created a big challenge for coffee growers to dry their coffee. The artificial drying process has a great capacity for drying huge quantities of coffee in a short amount of time and is not affected by weather conditions because it uses fuel or wood as a source of energy. Artificial drying has been used for a long time, despite the fact that the initial cost of this method is very high, and it also requires additional costs for the firewood heat source.

To solve such a problem, large commercial coffee farms recently started using solar tunnel drier as an alternative coffee drying method. Solar tunnel dryers are assumed to improve product quality (color, texture, and taste) and reduce postharvest loss, product contamination by insects, microorganisms, and mycotoxin, and drying time up to 50% compared to the sun drying method [15]. The principle of greenhouse is used in the operation of solar driers, where solar energy is trapped by manifolds that raise the temperature of the air. The use of solar dryer also protects the coffee beans from adverse weather conditions [14]. The reduction of moisture content from 55% to 11% in wet basis within a span of four days has been reported for parchment coffee dried by solar dryer in Ethiopia [16]. However, little is known about its effect on coffee quality in Ethiopia.

The quality of coffee also depends on the genetic makeup of the genotype. Variation of coffee quality among coffee varieties has been reported by many authors [5, 6, 10]. Therefore, this study was initiated with the hypothesis of semiwash processing and solar tunnel drying method has a significant effect on the quality of coffee varieties in Ethiopia. Therefore, the objective of the present study was to evaluate the influence of coffee processing and drying methods on the preliminary quality and specialty cup quality of coffee varieties at Limmu Kossa and Gomma I commercial coffee farms, southwest Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was carried out at Limmu Horizon coffee plantation farms located at Gomma I (7°57′N and 36°42′E; elevation of 1400–2270 masl) and Limmu Kossa (7°57N′ and 36°53′E; elevation of 1600–2000°m.a.s.l) of Jimma Zone, Oromia Regional State, southwest Ethiopia. The weathering profile of Gomma I is characterized by annual mean temperature and rainfall of 21.7°C and 1600 mm, respectively. Limmu Kossa is characterized by annual rainfall of 1920 mm and annual average minimum and maximum air temperatures of 12°C and 27°C, respectively. The area is located in the coffee-based farming system of the country.

2.2. Experimental Treatment. The experiment consisted of two processing methods (fully wash and semiwash) and three drying methods (solar tunnel, artificial, and natural sun) using three improved Arabica coffee varieties (741, 7440, and 74110) at two study locations (Gomma I and Limmu Kossa). The different varieties used in this experiment were purposely selected due to their popularity in the study area; they are being cultivated by most coffee producers because of their resistance to coffee berry disease and high yielding capacity.

2.3. Sample Preparation. For the purpose of uniform processing, red and ripe coffee cherries were selectively harvested from each variety at each study site during the peak harvesting period, in the month of November. At each location, a total of 54 samples (3 Varieties X 2 Processing Methods X 3 Drying Methods X 3 Replications) were collected. For the fully washed coffee processing method, ripe coffee cherries were separately pulped by using a coffee pulper machine (Aagaard Pregrader, McKinnon, Brazil). Immediately after pulping, the parchment coffee was sorted from the pulp and soaked underwater to separate the floaters. Then, the heavier parchment coffee was allowed to ferment in the fermentation tank for 24 hours. After degrading the slippery mucilage, the parchment coffee was further cleaned through washing and soaked with clean water for 24 hours. After removing the mucilage, the parchment coffee was subjected to predrying or partial sun drying.

For semiwashed coffee, the coffee cherries were introduced into a demucilaging machine (Mucilage remover, Pinhalense, Brazil) to remove pulp and mucilage. Then, the parchment coffee was washed with pure water to remove the remaining mucilage. After removing the mucilage, the parchment coffee was washed with clean water and subjected to predrying. In both processing methods, the predrying was performed on raised beds, which reduced the moisture content of the parchment coffee by approximately from 60% to 30%. After predrying, each sample of parchment coffee was subjected to three drying methods (natural sun, solar tunnel, and artificial drier) until the moisture content of 11.5% was achieved for each drying method at each study site.

During the study period, the ambient air temperature in the study location was 21–23°C, the room temperature for the solar tunnel drier was 35–40°C, and the artificial dryer was 90°C. Finally, the sun drying method takes 8 days, the solar tunnel dryer 4 days, and the artificial drying method takes 30 hours to dry the parchment coffee to 11.5 percent moisture content after predrying.

2.4. Data Collection and Quality Analysis. For quality analysis, each coffee sample having 1 kg dried coffee parchment was coded and taken to the Ethiopia Commodity Exchange (ECX), Jimma Branch, for physical and cup quality analysis. A coffee hulling machine (Coffee huller, Pinhalense, Brazil) was used to de-husk the dried coffee parchment with a moisture content of around 11.5 percent. For physical and cup quality analysis, 350-g clean coffee beans were used for each sample. During physical analysis, each coffee sample was evaluated for their primary and secondary defects, shape and make, color, and odor according to ECX [17] (Table 1) quality analysis procedure. The primary defects include fully black beans, full sour beans, fungus-attacked beans, broken beans, insect-damaged beans, pod/husk, and foreign matter, while the secondary defects considered include partial black, partial sour, floater, immature, foxy, under/over dried beans, faded/starved beans and stinkers, faded/coated beans, and light/starved beans [17].

For cup quality analysis, 100 g of coffee sample was roasted at 160–200°C for 8–12 min using a roasting machine (4 Barrel Roaster; Probat, Emmerich am Rhein, Germany) adjusted to medium roasting. The roasted beans were tipped out into a cooling tray and rapidly cooled by blowing cold air through the beans for 4 min and then ground with a coffee grinding machine (K32SB2; Mahlkonig, Hamburg, Germany). Next, 13.75 g of ground coffee was diluted in 250 mL of hot water (93°C) to prepare an infusion. Five cups of brewed coffee of each coffee sample were prepared for analysis, and a team of three professional cuppers, who operate in ECX, tasted and gave a score for each of the five cups.

The cup quality was determined on the basis of the level of acidity, body, flavor, and cup cleanness of the brew according to the standards of ECX [17] (Table 2). Thus, the sum of four cup quality attributes (cup cleanness, acidity, body, and flavor) accounts for the preliminary cup quality score of 60 percent, while the physical analysis (primary, secondary, shape and make, color, and odor) accounts 40 percent of the score.

Hence, preliminary total quality scores (physical and cup quality), between 0 and 100, were used to grade the coffee beans into different grades according to the standard of ECX [14] (Table 3).

Those coffee samples with grades from *l* to 2 in the preliminary assessment (Table 3) were further assessed for the potential of specialty coffee based on the standards of ECX [17]. Those samples were further evaluated for their fragrance, flavor, after taste, acidity, body, uniformity, balance, clean cup, sweetness, and overall, each account for 10 percent of the evaluation [17]. The sum of these cup quality attributes gives total specialty cup quality scores ranging from 0 to 100. Hence, those coffee samples that have got grade 1 (score ≥85 percent) and grade 2 (score in the range of 80–84.75) qualify for specialty coffee and are further grouped into specialty 1 (Q1) and specialty 2 (Q2), respectively [17].

2.5. Statistical Analysis. The collected data were checked for the assumption of analysis of variance (ANOVA) (normality, homogeneity, and constant variance) before being subjected to the analysis using the SAS computer software version 9.3. The procedure of Proc general linear model was employed to determine the significant effect of the factors involved on the preliminary and specialty coffee quality analysis. The collected data from two production areas were combined after checking the homogeneity of error variance (i.e., error variance difference between the two locations was small). Significant differences between treatment means were determined using the least significant difference (LSD) test at 5% probability level.

3. Results and Discussion

3.1. Primary and Secondary Defects. The primary defect was significantly affected by the interaction effect of location with processing methods, drying methods, and varieties. At both locations, less primary defect was recorded from coffee varieties processed by the semiwashed method (Table 4). Except for the artificial dryer at Gomma I, the coffee drying methods employed produced less primary defect at both locations (Table 5).

The relatively absence of primary defects may be due to proper harvesting of red ripe cherries during harvesting followed by proper handling during processing steps. However, the little difference observed among the treatment combination could be associated with the fungus and insect damage observed on coffee beans in the study area. These damages were observed in both locations during coffee harvesting periods. In addition, broken beans that resulted during processing and drying time might be attributed to the difference. Different studies reported that defects may be occurred during different stages of coffee production such as harvesting, processing, and drying of coffee beans, which results in cup quality deterioration [18, 19]. Tolessa [20] reported that well-harvested and properly processed coffee beans have no or very few broken beans and are free of foreign matters such as sticks, stones, and leaves.

The interaction effect between location and drying method was also significantly influenced the secondary defects of coffee beans. Similar to primary defect, except artificial dryer at Gomma I, the coffee drying methods employed produced less secondary defect at both locations (Table 5). In general, semiwashed processing method and solar tunnel drying method produce nondefective (primary and secondary) coffee beans compared with the other processing and drying methods at both

Table 1: Standard parameters and their respective values used for washed coffee raw (physical) quality evaluation (ECX, 2015).

Raw value (40%)									
Defects (20%)				Shape and make (5%)		Color (5%)		Odor 10 (%)	
Primary (count) (10%)	Point (Pts)	Secondary (wt) (10%)	Pts	Quality	Pts	Quality	Pts	Quality	Pts
1	10	≤5%	10	Very good	5	Bluish	5	Clean	10
2–5	8	≤8%	8	Good	4	Grayish	4	F. clean	8
6–10	6	≤10%	6	F. good	3	Greenish	3	Trace	6
11–15	4	≤12%	4	Average	2	Coated	2	Light	4
15–20	2	≤14%	2	Small	1	Faded	1	Moderate	2
>20	1	≤14%	1					Strong	1

Table 2: Standard parameters and their respective values used for washed coffee cup quality evaluation (ECX, 2015).

Cup quality value (60%)							
Cup cleanness (15%)		Acidity (15%)		Body (15%)		Flavor (15%)	
Type	Point	Type	Point	Type	Point	Type	Point
Clean	15	Pointed	15	Full	15	Good	15
Fairly clean	12	M. pointed	12	M. full	12	Fairly good	12
1 cup defect	9	Medium (M)	9	Medium (M)	9	Average	9
2 cup defect	6	Light	6	Light	6	Fair	6
3 cup defect	3	Lacking	3	Thin	3	Commonish	3
>3 coffee defect	1	Not detected	1	Not detected	1	Not detected	1

Table 3: Grading standards of Ethiopian washed commercial coffee (ECX, 2015).

Grade	Total value (raw value + cup quality value)
Grade 1	≥85
Grade 2	75–84
Grade 3	63–74
Grade 4	47–62
Grade 5	31–46
UG (P)	15–30
UG (NP)	15–30

locations. Coffee samples processed by demucilager with soaking produced superior overall standards compared with those processed with natural fermentation [10].

3.2. Shape and Make. The shape and make of the coffee beans were significantly influenced by varieties and processing methods. Higher mean value for shape and make was registered for variety 741 (4.47) and 74110 (4.44), while the lowest mean value (4.22) was from variety 7440. Similarly, coffee beans processed by the semiwashed method produced a higher mean value (4.50) of shape and make compared with the full wash processing method. In both cases, however, all the varieties and processing methods were categorized under good and very good grades for shape and make with a more uniform appearance (Table 6). Gure et al. [10] also indicated that varieties and processing methods significantly influenced the shape and make of coffee beans.

3.3. Color. The type of coffee processing method used has a significant effect on bean color (Table 6). Greenish color coffee beans were obtained from coffee beans processed by fully washed processing method, while grayish color coffee beans were obtained from coffee beans processed by semiwashed method (Table 6). This variation can be attributed to the different quantities of water applied in fully washed and semiwashed processing methods. The best coffee bean color can be obtained by removing the mucilage by fermentation underwater [10].

3.4. Body. The body of coffee beans was significantly influenced by coffee varieties and processing methods (Table 6). Coffee beans with more body were recorded from variety 741 to 7440, while the lower body was recorded from variety 74110. However, all coffee varieties were categorized under grade value of medium- to full-to-medium mouth feels [17]. Coffee beans processed by semiwashed method produced more body than wet processing method. The semiwash processing method produced the medium-full body, which is the second most acceptable cup quality value for coffee bean quality [17]. The three drying methods have not shown a significant effect on the body of the coffee bean.

3.5. Acidity. All coffee varieties processed by semiwashed method produced medium pointed acidity, second most acceptable grade value for coffee quality next to pointed [17], for all drying methods employed (Table 7). On the other hand, the lowest mean value (9.50, medium grade value) was registered for variety 74110 processed by fully washed method and dried by artificial drying method. This result indicated that relatively more acidity could be obtained for coffee varieties processed by the semiwashed method than the fully washed method. This difference can be due to the different steps undertaken; more water use in the fully

Table 4: Interaction effect of location and processing methods on primary defect of coffee beans and preliminary total quality.

Location	Processing methods	Primary defect	Preliminary total quality
Gomma I	Fully washed	9.55b	83.55bc
	Semiwashed	9.77ab	84.41ab
Limmu Kossa	Fully washed	9.11c	82.52c
	Semiwashed	10.00a	84.74a
LSD (0.05%)		0.39	1.08
CV (%)		6.71	1.86

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

Table 5: Interaction effect of location and drying methods on primary and secondary defect and preliminary total quality of coffee beans.

Location	Drying methods	Primary defect	Secondary defect	Preliminary total quality
Gomma I	Sun	9.89a	9.89a	84.44ab
	Solar tunnel	10.00a	9.67a	85.22a
	Artificial	9.11b	8.56b	82.27c
Limmu Kossa	Sun	9.56ab	9.56a	84.11ab
	Solar tunnel	9.56ab	9.33a	83.33bc
	Artificial	9.56ab	9.44a	83.44bc
LSD (0.05%)		0.51	0.59	1.28
CV (%)		6.71	7.18	1.86

Mean values followed by the same letter within a column are not significantly different at $P = 0.05$

washed processing method might lead to removing the acid content of the coffee beans. This finding is in line with the previous studies [10] who reported that coffee beans processed by de-mucilage machine produce high acidity levels. Similarly, the study indicated that sun and solar tunnel drying methods registered more acidity than artificial drying methods. Solar dryer improves the coffee quality [14, 16].

3.6. Flavor. The flavor of the coffee beans was significantly affected by the coffee processing and drying methods employed. Coffee beans processed by the fully washed method produced more flavor than the semiwash processing method (Table 8). It produced a fairly good flavor, the second most acceptable grade value in cup quality next to good [17]. Coffee beans dried by sun and solar tunnel drying methods also produced better flavor than artificial drying (Table 8). This finding is in line with previous studies [10] who reported that fully washed coffee samples have good flavor cup quality. The present finding supports the study by Musebe et al. [21], who reported that sun drying could produce high-quality coffee under good ambient conditions. Solar tunnel dryer is also used to reduce spoilage and improve product quality, which could improve the flavor of coffee beans. The solar dryer produces clean beans and smell as the coffee beans are not in contact with dust or Earth, and contamination from animal excrement or other refuse is avoided [16].

3.7. Preliminary Total Quality. The total preliminary quality of coffee beans was influenced by processing methods. The semiwash processing method produced a higher total preliminary quality value compared with fully washed coffee beans at both locations (Table 4). Natural sun and solar tunnel drying methods produced better total preliminary quality value compared with artificial drying method at both locations (Table 5). Particularly, at Gomma I the coffee beans dried by solar tunnel dryer were graded under grade 1. In general, all coffee varieties processed by semiwash method and dried by the natural sun, and solar tunnel produced more total preliminary quality value compared with other methods employed (Table 7). Coffee beans processed by the semiwash method and dried by the natural sun, and the solar tunnel was graded under grade 1.

3.8. Total Specialty Cup Quality. Total specialty cup quality was significantly influenced by the four-way interactions of location, variety, processing, and drying methods (Table 9). The highest mean value (85.50) was registered for variety 74110 grown at Limmu Kossa and processed by semiwashed method and dried by sun-drying method, which was categorized under specialty Grade Q1. On the other hand, the lowest mean value 81.41 was registered for variety 7440 grown at Limmu Kossa and processed by fully washed method and dried by artificial drying method, which was categorized under specialty grade Q2.

The findings of the present study indicated the highest total specialty cup quality for variety 74110 grown at Limmu Kossa and processed by semiwashed method and dried by sun-drying method. According to the present study, semiwashed processing method showed an economical and effective method for producing the highest total specialty cup quality compared with the fully washed method. The present study is in line with the work of Gure et al. [10] who reported that coffee samples processed by demucilager with soaking showed superior overall standards compared with those processed with natural fermentation. Similarly, sun and solar tunnel drying methods showed superior for producing the highest total specialty cup quality coffee compared with the artificial drying method. The study's finding is in

Table 6: The effect of variety and processing methods on the shape and make, color, and body of coffee beans.

Variety	Shape and make	Color	Body
741	4.47a	3.56	11.00a
7440	4.22b	3.31	10.58a
74110	4.44a	3.44	9.75b
LSD (0.05%)	0.21	NS	0.47
CV (%)	10.48	13.62	11.85
Processing methods			
Fully washed	4.26b	3.66a	9.89b
Semiwashed	4.50a	3.20b	11.00a
LSD (0.05%)	0.18	0.18	0.47
CV (%)	10.48	13.62	13.62

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

Table 7: The interaction effect of variety, processing, and drying methods on acidity and preliminary total quality.

Coffee variety	Processing method	Drying method	Acidity	Preliminary total quality
741	Wet processing	Sun	10.00cd	83.50bcde
		Solar tunnel	11.50ab	83.33cde
		Artificial	11.00abc	82.83cdef
	Semiwashing	Sun	12.00a	86.67a
		Solar tunnel	12.00a	85.67ab
		Artificial	12.00a	83.33cde
7440	Wet processing	Sun	10.00cd	82.33ef
		Solar tunnel	10.00cd	84.00bcde
		Artificial	12.00a	82.50def
	Semiwashing	Sun	12.00a	85.00abc
		Solar tunnel	12.00a	84.83abd
		Artificial	12.00a	84.50abcde
74110	Wet processing	Sun	10.00cd	83.33cde
		Solar tunnel	10.50bcd	84.67abcd
		Artificial	9.50 d	80.83f
	Semiwashing	Sun	10.50bcd	84.83abc
		Solar tunnel	11.50ab	83.17cde
		Artificial	12.00a	83.17cde
LSD (0.05%)			1.27	1.27
CV (%)			10.39	1.86

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

Table 8: The influence of processing and drying methods on flavor of coffee beans.

Processing methods	Flavor
Fully washed	11.17a
Semiwashed	9.22b
LSD (0.05%)	0.40
CV (%)	10.28
Drying methods	
Sun	10.50a
Solar tunnel	10.25ab
Artificial	9.83b
LSD (0.05%)	0.49
CV (%)	10.28

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

Table 9: The interactive effect of location, variety, processing, and drying methods on total specialty coffee cup quality.

Variety	Processing methods	Drying methods	Location: Gomma I	Location: Limmu Kossa
741	Fully washed	Sun	85.00ab	84.83abcd
		Solar tunnel	83.66efgh	83.58efgh
		Artificial	82.91hijk	82.83hijk
	Semiwashed	Sun	84.00cdef	84.75abcd
		Solar tunnel	83.66efgh	84.25bcde
		Artificial	82.08kl	83.58efgh
7440	Fully washed	Sun	83.41efgh	83.25fghij
		Solar tunnel	83.50efghi	82.16kl
		Artificial	82.33jkl	81.41l
	Semiwashed	Sun	83.50efghi	83.50efghi
		Solar tunnel	83.91defg	82.91hijk
		Artificial	82.33jkl	82.83hijk
74110	Fully washed	Sun	84.75abcd	82.58ijk
		Solar tunnel	84.75abcd	83.58efgh
		Artificial	82.25kl	83.41efghi
	Semiwashed	Sun	83.41efghi	85.50a
		Solar tunnel	83.41efghi	83.41efghi
		Artificial	82.16kl	84.91abc
LSD (5%)			0.94	
CV (%)			0.69	

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

agreement with previous studies [21, 22] who reported that sun-drying produces better coffee quality following appropriate management under good ambient conditions. Gachen et al. [16] also reported that solar tunnel dryer improves the quality of coffee beans.

4. Conclusion

Coffee beans processed by the semiwash method, in general, produced fewer primary defects, good shape and make, better body, acidity, and preliminary total quality, while the wet processing method produced better color and flavor for coffee beans. The effect of the processing method on secondary defects is a bit complex. Solar tunnel dryers and natural sun drying methods produced less primary and secondary defects at both locations. The three drying methods produced better acidity and flavor but had no significant effect on the body of coffee beans. In general, coffee beans processed by semiwash and dried by the natural sun and solar tunnel drying methods produced specialty coffee grade Q1. Hence, coffee growers in the study area can use the semiwash processing method and solar tunnel dryer as an alternative/complementary processing method since they produce a better or equivalent quality product with a full wash and natural drying method, respectively. Farmers in the study are can use semiwash when there is the shortage of water, and solar tunnel dryer where there is a problem of rain during drying.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

No potential conflicts of interest are reported by the author(s).

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