

## THE OCCURRENCE OF INSECTS, FUNGI AND ORGANOLEPTIC CHARACTERISTICS IN STORED COFFEE BEANS IN LAMPUNG

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### ABSTRACT

A survey on postharvest handling and technology processing of coffee beans at farmer, trader and exporter levels was conducted in West Lampung and Tanggamus regencies of Lampung province during harvest time (July 1998). Interviews and sampling of coffee beans were carried out during the survey. The number of respondents at farmer, trader and exporter levels was 22, 20 and 4, respectively, while the number of samples collected from each level was 20. All samples were analyzed for moisture content, physical quality, insect and fungal infestation, reducing sugar content, and coffee cupping.

The results of the interviews indicated that postharvest handling and technology processing became better from farmers to exporters.

Moisture contents of coffee beans collected from farmers and traders were higher than the tolerable limit recommended by SNI (13%). Physical quality of coffee beans collected from exporters was higher than that collected from farmers and traders. Insects were found on coffee beans collected from farmers, traders and exporters, but the number of species and the percentage of samples infested by insects from each level were relatively low. The predominant species was *Liposcelis entomophila*. The number of fungal species on coffee beans collected from farmers was higher than that collected from traders and exporters. The predominant species at the three levels was *Aspergillus niger*, but the lowest percentage of beans infected by this fungus was found on coffee beans collected from exporters. The lowest percentage of samples infected by all fungi was also found on coffee beans collected from exporters.

Reducing sugar content of coffee beans collected from exporters was lower than that from farmers and traders. Aroma and flavor values tended to increase from farmers through traders to exporters, while the body decreased. Some off-flavors (i.e. earthy, mouldy, fermented and woody) were encountered in a few coffee samples from farmers as well as from traders. There was no off-flavor encountered in the coffee samples from exporters.

**Key words:** Stored products pests/Postharvest handling/Technology processing/Moisture content  
Physical quality/Insect/Fungi/Reducing sugars/Coffee cupping/Coffee/ Lampung.

### INTRODUCTION

People all over the world are all facing global competitiveness. With the advent of wider market access and perceived increase in demand for farm products, we face the responsibility of maintaining the sustainability of our resources through appropriate research program in postharvest. It would minimize postharvest losses which in turn should benefit our farmers in terms of higher productivity and incomes. Food self-sufficiency can be attained by increasing production and minimizing food losses and quality degradation resulting from irjefficient postharvest handling.

Coffee is one of the important export commodities in Indonesia. Licht (1995) reported that Indonesia is the biggest coffee producer in Asia. Based on data from the Central Bureau of Statistics (1996) between January - September 1996; Indonesia has exported 253 027 tons of coffee beans. Most of coffee beans production is derived from smallholders.

During storage, coffee beans could be infested by insects, mites, microorganisms and rodents. Insects are considered the most significant cause of losses. Among microorganisms, fungi are the most important cause of deterioration of stored products. The role of insects on fungal infection cannot be disregarded. Aside from injuring seeds, insects also serve as carriers of fungi. Furthermore, the metabolic activities of insects produce enough heat and moisture (specially during longterm storage) to allow fungal growth.

No intensive study has been carried out on the occurrence of insects and fungi on stored coffee beans in Indonesia.

The objective of this study was to get information on postharvest handling and technology processing of coffee beans at farmer, trader and exporter levels in Lampung province. The moisture content, physical quality, pest infestation (insect and fungi), reducing sugar content and coffee cupping (organoleptic test) of coffee beans were also analyzed.

## **MATERIALS AND METHODS**

### Time and location of surveys

A survey was conducted during harvest time (July 1998) in two regencies, i.e. West Lampung regency (Fajar Bulan and Sumber Jaya villages) and Tanggamus regency (Data-rajan, Air Naningan, Way Harong, Gunung Megang and Tekad villages). These regencies were selected because they produce large quantities of coffee beans.

### Interviews using questionnaires

Interviews were carried out during the survey to get information on postharvest handling and technology processing of coffee beans at farmer, trader and exporter levels. The number of respondents from each level was different depending on the condition in the field during the survey. The number of respondents from farmers, traders and exporters was 22, 20 and 4, respectively. The questionnaires contained questions on postharvest handling and technology processing carried out by farmers, traders and exporters, and problems encountered by them.

### Sampling methods

The number of samples taken from each level was 20. Not all samples were derived from the respondents. About 1 kg of each sample was taken randomly from

farmer, trader and exporter levels. Samples of coffee (primary samples) from each stack were taken randomly from a certain number of sacks using a sampling spear. Insects were separated from each primary sample using graded sieves. Each primary sample was divided several times using a sample divider to obtain working samples for analyzing moisture content, physical quality, fungi, reducing sugars, organoleptic test and reserve sample. The presence of insects was estimated within the sacks.

### Moisture content analysis

Moisture content of coffee beans (wet weight) was determined by the oven method (ISC 1992). Two replicates were used for each sample. The beans were ground and dried in the oven at  $130 \pm 2^\circ\text{C}$  for 6 hours (first period), and then they were placed in a desiccator for a night. They were re-dried in the oven at  $130 \pm 2^\circ\text{C}$  for 4 hours (second period). The moisture content was determined using the formula:

$$\text{Moisture content} = P_1 + \left[ \frac{P_2 - P_1}{2} \right]$$

where :  $P_1$  is the first period moisture content (in 100 g of sample)  $P_2$  is the second period moisture content (in 100 g of sample)

### Physical quality analysis

Physical quality analysis was determined based on SN1 01-2907-1992 (ISC 1992). Quality level of coffee bean samples was determined based on the number of defective beans from 300 g of sample. Quality classification based on defective beans system and determination of the number of defective beans are shown in Tables 1 and 2.

Table 1. Quality classification based on defective beans system

Grade	Criteria of grade
Grade 1	Maximum number of defective beans 11
Grade 2	Number of defective beans 12-25
Grade 3	Number of defective beans 26 - 44
Grade 4-A	Number of defective beans 45-60
Grade 4-B	Number of defective beans 61-80
Grade 5	Number of defective beans 81-150
Grade 6	Number of defective beans 151 - 225

Notes : The number of defective beans was determined based on Table 2.

Table 2. Determination of the number of defective coffee beans

No.	Kind of defective	Defective value
1.	1 (one) black bean	1 (one)
2.	1 (one) a half of black bean	1/2 (a half)
3.	1 (one) broken black bean	1/2 (a half)
4.	1 (one) cherry bean	1 (one)
5.	1 (one) brown bean	1/4 (a quarter)
6.	1 (one) big husk	1 (one)
7.	1 (one) middle husk	1/2 (a half)
8.	1 (one) small husk	1/5 (one fifth)
9.	1 (one) bean with hull	1/2 (a half)
10.	1 (one) big hull	1/2 (a half)
11.	1 (one) middle hull	1/5 (one fifth)
12.	1 (one) small hull	1/10 (one tenth)
13.	1 (one) broken bean	1/5 (one fifth)
14.	1 (one) immature bean	1/5 (one fifth)
15.	1 (one) bean with one hole	1/10 (one tenth)
16.	1 (one) bean with more than one hole	1/5 (one fifth)
17.	1 (one) big branch, soil, or gravel	5 (five)
18.	1 (one) middle branch, soil, or gravel	2 (two)
19.	1 (one) small branch, soil, or gravel	1 (one)

Notes : If one bean has more than one kind of defective, the defective value was determined based on the highest defective value.

### Insect and fungal analyses

The insects were identified using Haines (1991) as the main reference. Fungi were isolated using direct plating method on Dichloran 18% Glycerol Agar (DG18) (Pitt and Hocking 1997). Before plating, samples were individually disinfected using 1% sodium hypochlorite for 1 minute. One hundred beans were then plated (10 beans/plate) on the medium and incubated at 25°C for 7 days. The fungi were identified using Samson *et al.* (1996), and Pitt and Hocking (1997) as the main references.

### Reducing sugars analysis

Reducing sugars (dry weight) was determined according to Somogyi Nelson's method (McCready 1970). In alkalic condition, reducing sugars reduce  $\text{Cu}^{2+}$  to  $\text{Cu}^+$ . Alkalies give a specific color if added with arsenicmolibdat and the absorbency of the color was measured by spectrophotometer on wave length 510 nm. Reducing sugars was determined using standard curve and glucose as a reference.

### **Organoleptic test analysis**

Coffee cupping was determined according to Lingle's method (1986). Coffee bean samples were roasted using Probat roaster Type PRE-2 at 200°C until medium roast level (color degree of # 55 Agtron/Specialty Coffee Association of America). Roasted coffee was then ground at medium grind degree. One hundred fifty ml boiling water was added to about 10 g of roasted and ground coffee. The test was carried out by 4 experienced panelists on aroma, flavor, body, and defect characteristics. Evaluation for each character was determined by numerical system (scoring): 0 = none, 1 = low, 2 = low-medium, 3 = medium, 4 = medium-high, 5 = high, respectively.

## **RESULTS AND DISCUSSION**

### **Interviews with farmers, traders and exporters**

#### **a. Farmer level**

The results of the questionnaires are shown in Appendix 1. Most of the farmers (77.3% respondents) cultivated only robusta coffee, while others (22.7%) cultivated arabica and robusta coffee, especially in West Lampung. Determination of harvest time was based on visual observation of the color of the berry. The ripeness of coffee berry is indicated by its red color. Nevertheless, strip methods of harvesting was carried out when the number of ripe berries was about 80%.

The drying process was carried out by farmers. Most of the farmers (63.6%) dried the coffee directly without opening the berries, and consequently they stored the coffee in the form of dried coffee berries. The others (36.4%) opened the berries using a machine before drying. The final form obtained was called green coffee. Applying this method, coffee beans would dry faster, and thus farmers could sell them faster.

The drying facilities used by farmers were varied, i.e. on the ground, on a plastic (polypropylene) sheet and on paved floor. Farmers revealed that in general there was no problem with insects as well as fungi in the storage.

#### **b. Trader level**

The results of questionnaires are shown in Appendix 2. Traders bought coffee beans from farmers, although the moisture content was still high (20-30%). In this case, the farmers gave a discount for the undesirable moisture content of the coffee beans. Most of traders (85.7%) further sun-dried their coffee beans for less than 1 day or only several hours.

Traders dried coffee beans on polypropylene sheet (42.9%) and paved floor (57.1%). In general, traders stored the beans for not more than 2 days by spreading them on the floor in their warehouse/store (65%) and the beans were packed using plastic bags (30%).

Most of traders (60%) sorted and selected the beans that will be sold to exporters, because exporters classified the price of beans based on moisture content and physical quality (i.e. percentage of extraneous matter, hulls, beans with holes and black beans).

Most of the traders did not have any problem with insects and fungi. Nevertheless, if mouldy beans were found, no action was taken by 65% of the respondents.

### **Exporter level**

The results of questionnaires are shown in Appendix 3. Exporters in Lampung obtained coffee beans from traders in Lampung province, Java and other provinces in Sumatera. Determination of price classification was based on moisture content and physical quality of the beans. The beans were packed in jute bags (91.7%) and plastic bags (8.3%) before reprocessing (further dried, sorted and sifted). The duration of storage was usually less than 1 week. Further drying was carried out using a mechanical dryer up to moisture content of 12-13%. Sorting was conducted using an electronic sorting machine (sortex) to discard extraneous matter and black beans. After sorting, grade quality could be determined. The beans were then packed in jute bags or containers, fumigated, and finally exported. Generally, fumigation was conducted by private companies in warehouses or in the containers depending on customer demand. The fumigant used was methyl bromide (87.5% of respondents) or phosphine (12.5%) depending on customer demand and importing countries.

All exporters monitored insect pest infestation. Most of them (75%) did not have any problem with insect pests, while the others (25%) did.

### **Moisture content and physical quality**

Moisture content of coffee beans collected from farmers ( $16.1 \pm 1.3\%$ ) and traders ( $16.5 \pm 3.3\%$ ) were higher than the tolerable limit recommended by SNI (13%). All the samples (100%) collected from farmers has a moisture content of more than 13%. Similar moisture content was obtained from 90% samples collected from traders (Table 3). Based on statistical analysis, moisture content of coffee beans from farmers was not significantly different compared to coffee beans collected from traders, but that from traders was more varied.

Moisture content of coffee bean samples from exporters ( $12.6 \pm 0.5\%$ ) (Table 3) was lower compared to samples from farmers and traders, but 20% of the total samples collected from exporters still exceeded the tolerable limit recommended by SNI. Exporters re-processed the coffee from traders to meet the standard. The

Table 3. Moisture content and physical quality of coffee beans collected from farmers, traders and exporters

Source of coffee beans	Moisture content (%)	Grade of quality (% samples)	Number (%) of samples with moisture content > 13%
Farmers	16.1 ± 1.3 a	5 (10), 6 (90)	20 (100)
Traders	16.5 ± 3.3 a	6 (100)	18 (90)
Exporters	12.6 ± 0.5 b	4-A(10),4-B(15), 5 (20), 6 (55)	4(20)

Numbers followed by the same letter did not differ significantly according to Tukey's Test at 95% confidence level

Notes : Grade 4-A : samples of coffee beans with the number of defective bean 45-60  
 Grade 4-B : samples of coffee beans with the number of defective bean 61—80  
 Grade 5 : samples of coffee beans with the number of defective bean 81 - 150  
 Grade 6 : samples of coffee beans with the number of defective bean 151 - 225

process included drying, mixing, grading and packaging. Exporters dried coffee beans using mechanical dryers. The temperature of the dryer was set at 200°C or more; consequently, the moisture content of coffee beans from farmers and traders could be decreased from 16% up to about 13% within a short period.

Based on the number of defective beans, the quality of samples from traders was not better, it even tended to be of lower quality (100% of samples consisted of the lowest Grade 6) compared with that from farmers (10% of samples consisted of Grade 5 and 90% of samples consisted of Grade 6) (Table 3). Traders bought coffee beans from farmers against the price which is based on moisture content, number of defective beans and extraneous matter. Defective beans (black beans, brown beans, immature beans, broken beans and cherries) and the extraneous matter were counted arbitrarily by the traders. Most of traders possessed an electronic moisture tester (generally Cera Tester) which is used to determine the moisture content for pricing. Nevertheless, the tester had never been calibrated, thus the result of determination is unreliable. Traders mixed the coffee from farmers. As a consequence the mixing of high as well as low quality coffee resulted in downgrading.

In general, the physical quality of coffee beans from exporters was better (10% of samples consisted of grade 4-A, 15% of samples grade 4-B, 20% of samples grade 5 and 55% of samples grade 6) than that from farmers and traders (Appendix 2). Exporters sorted coffee beans obtained from traders in order to reduce the defects especially black beans and beans in cherry. The sorting process was conducted using electronic sorting machine. In addition, the coffee beans were also sieved with screens to get a uniform size and clean beans.

### The presence of insects

Haines (1991) reported that insect species associated with stored coffee beans were *Araecerus fasciculatus*, *Hetebostrychus brwmeus* and *Prostephanus truncatus*.

The number of insect species found in coffee bean samples collected from farmers, traders and exporters, and the percentage of samples infested by the insects were relatively low (Table 4). Similar results were reported by the respondents.

Table 4. Insect species found on coffee beans collected from farmers, traders and exporters

Insect species	0% samples infested by insects		
	Farmers	Traders	Exporters
<i>Ahasverus advena</i>	0	5	0
<i>Araecerus fasciculatus</i>	0	0	5
<i>Liposcelis bostrycophila</i>	10	0	30
<i>L. entomophila</i>	10	10	40
<i>Sitophilus zeamais</i>	0	5	0

In this study, insect species found on coffee beans collected from farmers were *Liposcelis bostrycophila* (10% of samples) and *L. entomophila* (10%) (Table 4). This result showed that insect infestation on coffee beans from farmers was relatively low, because farmers did not store the beans for a long period. The results of interviews using questionnaires showed that only 14.3% of farmers stored coffee beans for more than 3 days (Appendix 1). Haines (1995) reported that *L. entomophila* was found on 50% of samples of stored coffee beans in Java and Sumatera. In a tropical country like Indonesia, the predominant psocid (insect of genera *Liposcelis*) found were *L. bostrycophila* and *L. entomophila* (Leong and Ho 1991; Syarif and Halid 1993).

The role of psocids is not well understood, as to whether these insects eat or cause deterioration of stored commodities. Psocids are often found in humid warehouses (Syarif and Halid 1993). According to Sidik and Cahyana (1992), high populations of *Liposcelis* spp. made the warehouse dirty; consequently working activities were disturbed. Recently it was found that *Liposcelis* spp. were real stored product pests. Their heavy infestations on stored grains occurred in Indonesia, India and Australia (Roesli *et al.* 1998).

The occurrence of *L. bostrycophila* and *L. entomophila* on coffee beans at the farmer level was due to the high moisture content of the beans ( $16.1 \pm 1.3\%$ ) and the sanitary conditions of the storage facility which were not managed properly. In Indonesia, populations of psocids on rice have increased drastically several months after harvest (Santoso *et al.* 1996).

Three insect species were found on coffee beans at the trader level, namely *Ahasverus advena* (5% of samples), *L. entomophila* (10%) and *Sitophilus zeamais*

(5%) (Table 4). In general, *S. zeamais* is an insect pest found on milled rice, maize and pulses. The presence of the three insect species on coffee beans was due to migration, because the beans were stored in the stores located at traditional markets which sell milled rice and maize. *Ahasverus advena* is a fungus feeder. Its presence was due to high moisture content of coffee beans (10.5-22.7%). According to Haines (1991), *A. advena* often found on damaged and mouldy commodities in storage is an indicator of wet storage facility.

Three insect species were also found on coffee beans at the exporter level. They were *Araecerus fasciculatus* (5% of samples), *Liposcelis bostrycophila* (30%) and *L. entomophila* (40%) (Table 4). *L. bostrycophila* and *L. entomophila* were more often found at the exporter level than at the farmer and trader levels. This was because coffee beans stored by exporters were derived from farmers and traders and infested by those insects, resulting in their presence in greater numbers on the beans at the exporter. Besides that, frequent fumigation carried out by exporters affected the population of *Liposcelis* spp. According to Roesli *et al.* (1998), improper fumigation, i.e. shorter exposure period or too low gas concentration, caused an increase in populations of these insects.

*A. fasciculatus* is a major pest of stored coffee beans. Its presence caused damage to the beans, thus decreasing the selling value. Haines (1991) revealed that the presence of *A. fasciculatus* on export commodities such as coffee and cocoa beans could decrease the selling value, although the damage might not be heavy. This insect was also found on stored products in Lampung and South Sumatera (Haines 1995).

### The presence of fungi

Based on an interview, most of the respondents said that they had no problem with fungi. Their opinion was only based on visual observation. Nevertheless, based on fungal isolation using DG18, all beans were infected by fungi.

Fifteen fungal species were isolated on coffee beans collected from farmers. They were *Aspergillus flavus*, *A. niger*, *A. ochraceus*, *A. penicilloides*, *A. tamarii*, *A. versicolor*, *A. wentii*, *Cladosporium cladosporioides*, *Eurotium amstelodami*, *E. chevalieri*, *Fusarium semitectum*, *Lasiodiplodia theobromae*, *Mucor hiemalis*, *Penicillium citrinum* and *Wallemia sebi*. *A. niger* was the dominant fungus isolated, having been found in 100% of all samples, and 83.5% of all beans examined. *A. flavus* was the next most common fungus, being present in 90% of the samples, but only 12.3% of all beans examined. *P. citrinum* was present in only 15% of the samples and infected 18.7% of all beans examined (Table 5).

Ten fungal species were isolated on coffee beans collected from traders. They were *A. flavus*, *A. niger*, *A. ochraceus*, *A. penicilloides*, *A. tamarii*, *A. versicolor*, *A. wentii*, *E. chevalieri*, *L. theobromae* and *P. citrinum*. *A. niger* was also the dominant fungus isolated, being found in 100% of the samples, and 94.9% of all beans

Table 5. Fungal infection of 20 coffee bean samples collected from farmers, traders, and exporters, respectively average percentage of infected beans of all samples

No.	Fungal species	Farmer			Trader			Exporter		
		No. (percentage) of infected samples	Range of percent infection in infected samples	Average percentage of infected beans of all samples	No. (percentage) of infected samples	Range of percent infection in infected samples	Average percentage of infected beans of all samples	No. (percentage) of infected samples	Range of percent infection in infected samples	Average percentage of infected beans of all samples
1	<i>Aspergillus flavus</i>	18 (90)	1-46	12.3	18 (90)	1-95	14.1	20 (100)	2-69	11.9
2	<i>A. niger</i>	20 (100)	27-100	83.5	20 (100)	54-100	94.9	19 (95)	24-100	60.1
3	<i>A. ochraceus</i>	8 (40)	1-100	6.2	15 (75)	1-84	11.6	10 (50)	1-52	3.4
4	<i>A. penicillioides</i>	1 (5)	-	<1	3 (15)	3-8	<1	0	0	0
5	<i>A. tamaritii</i>	7 (35)	1-13	2.0	7 (35)	1-6	1.1	3 (15)	1-4	<1
6	<i>A. versicolor</i>	1 (5)	-	3.8	1 (5)	-	<1	0	0	0
7	<i>A. wentii</i>	4 (20)	1-20	1.4	7 (35)	1-7	1.1	2 (10)	1-3	<1
8	<i>Cladosporium</i>	2 (10)	1-4	<1	0	0	0	3 (15)	1-5	<1
	<i>cladosporioides</i>									
9	<i>Eurotium amstelodami</i>	6 (30)	1-82	6.4	0	0	0	0	0	0
10	<i>E. chevalieri</i>	3 (15)	1-83	4.3	3 (15)	2-13	<1	10 (50)	1-5	1.3
11	<i>Fusarium semitectum</i>	2 (10)	1-13	<1	0	0	0	1 (5)	-	<1
12	<i>Lastodiopodia</i>	12 (60)	1-10	2.2	17 (85)	1-7	2.3	2 (10)	1-3	<1
	<i>theobromae</i>									
13	<i>Mucor hiemalis</i>	6 (30)	1-75	4.0	0	0	0	7 (35)	1-16	2.0
14	<i>Penicillium citrinum</i>	3 (15)	1-100	18.7	15 (75)	1-100	30.7	15 (75)	1-28	3.7
15	<i>Wallemia sebi</i>	2 (10)	11-30	2.1	0	0	0	0	0	0

examined. *A. flavus*, *A. ochraceus*, *L. theobromae* and *P. citrinum* were all present in more than 75% of the samples, but their infection on all beans examined were relatively low (14.1, 11.6, 2.3 and 30.7%, respectively) (Table 5).

Eleven fungal species were isolated on coffee beans collected from exporters. They were *A. flavus*, *A. niger*, *A. ochraceus*, *A. tamarii*, *A. wentii*, *C. cladosporioides*, *E. chevalieri*, *F. semitectum*, *L. theobromae*, *M. hiemalis* and *P. citrinum*. The most commonly occurring species was *A. niger*, present in 95% of samples, and 60.1% of all beans examined. *A. flavus* and *P. citrinum* were found in 100 and 75% of samples, respectively, but infected only 11.9 and 3.7%, respectively, of all beans examined (Table 5).

According to Scott (1994) and Ono *et al.* (1995) *A. niger* and *A. ochraceus* could produce ochratoxin A. This toxin caused a swelling of the kidneys (nephropathy) in domestic livestock and poultry, and it has been considered as the causative agent responsible for human endemic nephropathy prevalent in areas of the Balkan countries (Prelusky *et al.* 1994) and Tunisia (CCFAC 1998).

Among the three levels, the number of fungal species isolated from coffee beans at the farmers level was the highest, because moisture content of all sample was more than 13% (Table 3). The dominant fungus isolated at the three levels was the same, i.e. *A. niger*, but the lowest infection of all beans examined among the three levels was found at exporter level, because the exporters further dried and sorted coffee beans obtained from farmers and traders. Moreover, among the three levels the lowest percentage of samples infected by all fungi was obtained from the exporter level (70.7%), while that at farmer and trader levels were not significantly different to each other (99.1 and 99.0%, respectively) (Table 6). Nakajima *et al.* (1997) reported that the dominant fungus isolated on coffee beans was *A. niger*.

Table 6. Percentage of samples infected by all fungi on coffee beans collected from farmers, traders and exporters

Source of coffee beans	Samples infected by all fungal species (%)
Farmers'	99.1 a
Traders	99.0 a
Exporters	70.7 b

Numbers followed by the same letter did not differ significantly according to Tukey's Test at 95% confidence level

### Reducing sugar content

Sugars are important components in the formation of flavor, color/pigment, caramelization and condensation products of roasted coffee. The major free sugar in coffee beans is sucrose, which reaches 6.1% in arabica coffee and 3.4% in robusta

coffee (Trugo 1985). Besides sucrose, coffee beans also contain simple sugars including reducing ones, but in small amounts. Fructose and glucose in arabica coffee constitute 0.030-0.038% and 0.023-0.030%, respectively, while in robusta coffee 0.16-0.18% and 0.19-0.21%, respectively. Reducing sugars in arabica and robusta coffees are only 0.1 and 0.5%, respectively (Trugo 1985).

Analysis of reducing sugars in the samples resulted in  $2.7 \pm 0.3\%$  for coffee from farmers,  $3.2 \pm 0.6\%$  for coffee from traders, and  $2.3 \pm 0.2\%$  for coffee from exporters (Table 7). Those results were higher than the reported data. Coffee beans from exporters had the lowest value compared to the coffee from farmers and traders. Those lower values were probably due to the coffee that had been further dried at quite high temperature, a condition which makes the sugars caramelized or condensed through the Maillard reaction, hence the amount was reduced. According to Winarno (1991) caramelization of sucrose occurred when the temperature is higher than the melting point ( $160^{\circ}\text{C}$ ); the Maillard reaction is a reaction among carbohydrates, especially of reducing sugars with primary amine groups yielding pleasant brown compounds.

Table 7. Reducing sugar contents of coffee beans collected from farmers, traders and exporters

Source of coffee beans	Reducing sugar content (%)
Farmers	$2.7 \pm 0.3$ b
Traders	$3.2 \pm 0.6$ a
Exporters	$2.3 \pm 0.2$ c

Numbers followed by the same letter did not differ significantly according to Tukey's Test at 95% confidence level

### Coffee cupping (organoleptic test)

Aroma and flavor characters of all coffee samples were termed as low-medium to medium, while their body character ranged from medium to full (Table 8). Coffee from Lampung is known for its unique taste with full bodied and unclean flavor. The unclean flavor is also frequently found in dry processed coffee beans. Some very low off-flavors like earthy, musty, and mouldy shadowing the coffee flavor resulted in a unique character.

Aroma and flavor values tended to increase for the coffee at farmer ( $2.4 + 0.4$  and  $2.5 + 0.5$ , respectively), trader ( $2.8 \pm 0.3$  and  $2.6 \pm 0.3$ , respectively), and exporter levels ( $2.9 \pm 0.1$  and  $2.9 + 0.2$ , respectively), while the body decreased with values of  $4.3 \pm 0.5$ ,  $3.6 \pm 0.2$ , and  $3.6 \pm 0.2$  for each coffee origin (Table 8). The aromatic characters of coffee beans from exporters was the strongest, it was probably due to caramelization during the drying process which further produced specific aroma.

TableS. Results of coffee cupping (organoleptic test) on coffee beans collected from farmers, traders and exporters

Source of coffee beans	Aroma	Flavor	Body	Off-flavor (% of samples)
Farmers	2.4 ±0.4	2.5 ±0.5	4.3 ±0.5	Earthy : 40 Mouldy : 5 Fermented : 5
Traders	2.8 +0.3	2.6 +0.3	3.6 +0.2	Earthy : 35 Woody : 5
Exporters	2.9 ±0.1	2.9 ±0.2	3.6 +0.2	-

Score: 0 = none, 1 = low, 2 = low-medium, 3 = medium, 4 = medium-high, 5 = high

Some off-flavors were encountered from few coffee samples from farmers as well as from traders, i.e. earthy (35% of samples), mouldy (5% of samples), fermented (5%), and woody (5%). There was no off-flavor encountered in the coffee samples from exporters. It was due to the mixing of defective beans with good beans that the off-flavor characters decreased and could not be detected by the panelists.

The soil odor was absorbed by fat in the beans causing an earthy flavor. The off-flavor was also caused by fungal infection, since some fungi could produce chemical compounds with earthy flavor, like 2-methylisoborneol and geosmin. The earthy off-flavor was higher in samples collected from farmers, since most farmers dried their coffee beans on the ground with no underlayer or mat used. This made the coffee cherry become dirty and the beans were covered with soil dust after de-hulling. Drying of coffee directly on the ground takes a longer time, since the moist ground hampers evaporation. It makes the coffee mouldy and tainted with the earthy and mouldy characters. The off-flavor could be avoided if the drying process was conducted on a sheet or mat, or on patio made of concrete. Sanitation along with the drying process should be emphasized, since the dirty coffee would be infected by fungi.

Mouldy off-flavor is also referred to as musty, which is an odor taint giving the coffee beans a mouldy odor, a result of fats in the coffee beans absorbing organic material from fungi during the drying process. This off-flavor is more pronounced than the earthy off-flavor. The defect may also appear during storage, if the coffee beans had not been dried properly. If the coffee beans from farmers and traders had a high moisture content ( $\pm 16\%$ ), it could be easily infected by fungi, especially the toxigenic fungi (see fungal analysis). Once the taint occurred, it would remain permanently. In order to avoid this defect, it is suggested that the coffee be dried at the very early stage of production (on the farm) properly, and the process be continued until the moisture content reaches below 13%. It is advisable not to store the coffee beans with high moisture contents.

Fermented off-flavor is an undesirable taste in the coffee beans that produces a strong unpleasant sour sensation or sting on the tongue. This defect is caused by the coffee cherries that had been kept or heaped for days, thus making sugars in the beans fermented and produce sour substances. Fresh cherries could be easily fermented, especially the pulp and mucilage parts. The increase in temperature and microorganisms present in the cherries will hasten the fermentation. The sour substances produced would be absorbed into the beans and taint the coffee. In order to avoid this defect, the fresh cherries had to be processed immediately. The fresh cherries should be dried on the patio soon after harvest. During the drying process, the cherries were frequently turned upside-down to hasten the process and to get more uniformly dried beans. Re-wetting by the rain should also be avoided.

No off-flavor was encountered in the coffee samples from exporters which showed quality improvement of the coffee beans collected from farmers and traders after being re-processed. The improvement was due to further drying, sorting out of bad beans, and mixing of coffee lots. The mixing of perfect and defective coffee beans could neutralize or dilute the off-flavor which makes the percentage of off-flavor beans present become very low and undetectable by panelists.

### **CONCLUSIONS**

Most farmers cultivated robusta coffee and they carried out the drying process to obtain commercial coffee beans. Postharvest handling and technology processing methods became better from farmers to exporters. Physical quality, pest infestation (insect and fungi), moisture content, reducing sugar content and coffee cupping of coffee beans also became better from farmers to exporters.

### **RECOMMENDATIONS**

Extension and dissemination of good handling practices for coffee beans especially at farmer and trader levels are necessary to improve the coffee postharvest handling and technology processing.

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Appendix 1. Results of questionnaires on postharvest handling and technology processing of coffee beans at farmer level

No.	Subject	% respondents
1.	Type of coffee cultivated:	
	a. robusta coffee ( <i>Coffea robusta</i> )	77.3
	b. arabica coffee ( <i>C. arabica</i> )	0
	c. both types of coffee	22.7
2.	Determination of harvest time was based on:	
	a. color of coffee berry	100
	b. size of coffee berry	0
	c. others	0
3.	Harvesting method of coffee berries:	
	a. selected method	9.1
	b. strip method	90.9
4.	Duration of storing coffee berries:	
	a. < 1 day	0.0
	b. 1-3 days	35.7
	c. > 3 days	14.3
5.	Storing method of coffee berries:	
	a. in bag	100
	b. in another container	0
	c. spreading out on the floor	0
6.	Opening of coffee berry before drying:	
	a. yes	36.4
	b. no	63.6
7.	Drying facilities:	
	a. ground	0.0
	b. plastic (polypropylene)	27.3
	c. paved floor	22.7
	d. other	0
8.	Duration of drying:	
	a. < 1 week	31.8
	b. 1-2 weeks	59.1
	c. > 2 weeks	9.1
9.	Methods for determining dried coffee beans:	
	a. experience/organoleptic	100
	b. using equipment for measuring moisture content	0
10.	Type of stored coffee beans:	
	a. dried coffee berries	63.6
	b. green coffee	36.4
11.	Duration of storing coffee beans:	
	a. < 1 week	95.4
	b. 1-2 weeks	4.6
	c. > 2 weeks	0
12.	Type of bag used for storing coffee beans:	
	a. jute bag	4.6
	b. plastic bag (polypropylene)	86.4
	c. others "	0
	d. spreading out on the floor	90

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Appendix 1. (continued)

No.	Subject	% respondents
13.	Postharvest problems:	
	a. pest infestation (insects and/fungi)	18.2
	b. processing facility	0
	c. none	81.8
14.	Mouldy beans problems:	
	a. yes	27.3
	b. no	2.7
15.	Information on postharvest of coffee:	
	a. yes	77.3
	b. no	22.7

Number of respondents: 22

Appendix 2. Results of questionnaires on postharvest handling and technology processing of coffee beans at farmer level

No.	Subject	% respondents
1.	Moisture content of coffee beans bought from farmers:	
	a. < 12%	0
	b. 12-15%	0
	c. 15-20%	0
	d. 20-30%	100
	e. >30%	0
2.	Methods for determining moisture content of coffee beans	
	a. using equipment (Cera tester)	75.0
	b. by estimating (organoleptic)	25.0
3.	Price classification of coffee beans based on:	
	a. moisture content	40.0
	b. moisture content and physical quality .	60.0
	c. other criteria	0
	d. no classification	0
4.	Drying method used:	
	a. sun-drying	93.3
	b. mechanical drying	6.7
5.	Drying facilities used:	
	a. ground	0
	b. plastic (polypropylene)	42.9
	c. paved floor	57.1
6.	Duration of further drying:	
	a. < 1 day	85.6
	b. 1-2 days	7.2
	c. > 2 days	7.2
7.	Storing method of coffee beans:	
	a. packed in jute bag	5.0
	b. packed in plastic bag (polypropylene) 30.0	
	c. spreading the coffee beans on the floor 65.0	

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Appendix 2. (continued)

No.	Subject	% respondents
8.	Duration of storing coffee beans in warehouse/store:	
	a. 1-2 days	70.0
	b. 2 days -1 week	30.0
	c. > 1 week	0
9.	Action conducted when mouldy beans were found:	
	a. further dried	35.0
	b. no action	65.0
10.	Pest problems encountered:	
	a. insects infestation	10.0
	b. fungal infection	0
	c. none	90.0

Number of respondents: 20

Appendix 3. Results of questionnaires on postharvest handling and technology processing of coffee beans at fanner level

No.	Subject	% respondents
1.	Price classification of coffee beans based on:	
	a. moisture content	0
	b. moisture content and physical quality	100
	c. no classification	0
2.	Further dried coffee beans obtained from traders:	
	a. yes	100
	b. no	0
3.	Drying method used:	
	a. sun-drying	0
	b. mechanical dryer (oven/mason dryer)	100
4.	Moisture content of coffee beans after further dried:	
	a. < 12%	0
	b. 12-13%	100
	c. > 13%	0
5.	Sorting coffee beans used:	
	a. manpower/manually	0
	b. electronic sorting machine (model sortex)	100
6.	Type of bag used for storing coffee beans before reprocessing:	
	a. jute bag	91.7
	b. plastic bag (polypropylene)	8.3
	c. bulk system	0
7.	Duration of storing coffee beans in warehouse/factory:	
	a. < 1 week	100
	b. 1-4 weeks	0
	c. > 4 weeks	0
8.	Pest monitoring:	
	a. yes	100
	b. no	0

Appendix 3. (continued)

No.	Subject	% respondents
9.	Fumigation of coffee beans before exported:	
	a. yes	10
	b. no	0
10.	Type of fumigant used:	
	a. phosphine	125
	b. methyl bromide	87.5
11.	Fumigation was carried out by:	
	a. the exporters	0
	b. private companies	100
12.	Fumigation site:	
	a. warehouse	25.0
	b. container	75.0
13.	Pest problems encountered:	
	a. insects infestation *	25.0
	b. fungal infection	0
	c. rat infestation/others	0
	d. none	75.0
14.	Complaint from importing countries:	
	a. coffee beans were infested by insects	25.0
	b. coffee beans were infected by fungi	0
	c. physical quality was not good	0
	d. coffee taste was not like desired	0
	e. none	75.0

Number of respondents: 4