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Post-harvest Fungal Infection in Arabica Coffee Beans (*Coffea arabica* Linnaeus) in the Coffee Center of West Sumatra Province, Indonesia

Infeksi Jamur Pascapanen pada Biji Kopi Arabika (*Coffea arabica* Linnaeus) di Daerah Sentra Kopi Arabika, Provinsi Sumatera Barat, Indonesia

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Abstract

Post-harvest fungi attacks in storage can reduce the quality of Arabica coffee. The study aimed to determine the level of infection and types of post-harvest fungi in Arabica coffee beans and their quality. The research was carried out at the Phytopathology Laboratory of Plant Pests and Diseases Department and the Seed Technology Laboratory of Agronomy Department, Agriculture Faculty, Universitas Andalas, Padang, from June to August 2021. The infection level of post-harvest fungi was detected using the blotter method. Physical quality was determined based on the percentage of defects, and the quality of the coffee beans was classified according to the Indonesian National Standard (SNI). The samples were taken from three collectors in each of the three central districts of Arabica coffee, West Sumatera province (Solok Selatan, Pesisir Selatan, Lima Puluh Kota) and one sample from Solok Radjo Cooperative as a comparison. The results showed that post-harvest fungi that attacked Arabica coffee beans in West Sumatra belong to the Aspergillus genus, namely *Aspergillus niger*, *A. flavus*, and *A. ochraceus*. The highest post-harvest fungi attack was from Lima Puluh Kota (63.67%), and the lowest was from Solok Radjo (27%). The fungus with the highest infection rate was *A. niger* (38.83%), and the lowest was *A. flavus* (0.53%). The best quality of Arabica coffee beans was found in Solok Radjo (quality 3), with a water content that suitable with SNI standards.

Keywords: Attack, *Aspergillus niger, Aspergillus flavus, Aspergillus ochraceus,* storage

Introduction

Coffee is an important commodity in world international trade. Indonesia accounts for 6.4% of coffee production on the global market and is the fourth largest coffee-producing country in the world after Brazil, Vietnam, and Colombia (ICO, 2021). Coffee plantations are very important for the Indonesian economy because they can create job opportunities that lead to people's welfare. West Sumatra Province has coffee plantations with an area of 32,525 hectares. The area of Arabica coffee is 14,879 hectares, with production reaching 9,272 tons in 2018. The Arabica coffee center area in West Sumatra includes Solok Selatan, Pesisir Selatan, and

Lima Puluh Kota Districts (West Sumatra Plantation Service, 2019).

Farmers sell Arabica coffee bean yields to collectors. Before being distributed, the beans are stored by collectors in warehouses to collect them in large quantities, but it will take a long time. This condition will affect the quality and quantity of beans due to the influence of abiotic factors, including the environment around the storage warehouse, and biotic factors, such as post-harvest fungi attacks (Yani, 2008). The fungi attacks on beans can cause discoloration, reduce physical quality and nutritional content, and be contaminated by mycotoxins (Dharma-putra, 2021). Dharmaputra (2016) states that the presence of post-harvest fungi in coffee beans is also related to the support of environ-mental factors such as water content, humidity, temperature, water activity, storage time, and type of substrate.

According to Yani (2007), post-harvest fungi, besides reducing quality, some types of these fungi produce ochratoxin A (OA). Lilia et al. (2021) reported that ochratoxins could be produced by *Aspergillus niger*, *A. ochraceus*, and *A. carbonarius* in the tropics, which can cause liver cancer, kidney failure, fever, degene-ration, and neurological disorders. According to Rosavani (2019), nine out of ten green coffee bean samples collected from the Argopuro mountain area in East Java Province were infected with OA, with the highest concen-tration of 0.4319 ppm and the lowest concen-tration of 0.0146 ppm. Many factors cause the high OA content, for example, contaminated by fungi and the quality of the processing used by farmers.

Silva et al. (2008) reported that the fungi that attacks Arabica coffee beans during storage in Brazil are dominated by the *Aspergillus* genera, namely *A. flavus* and *A. niger*. Al-Adalall and Al-Talib (2012) reported a fungus attack on Arabica coffee beans in several P&D stores during the storage period domina-ted by the Aspergillus (*A. niger*, *A. alliaceus*, and *A. melleus*) with an attack rate of up to 100% and the attack rate of *A. flavus* reached 71%. Dharmaputra et al. (2019) reported that the post-harvest fungus that infected Arabica coffee beans in South Sulawesi Province at the farmer and collector levels was *Penicillium citrinum*, 85% and 100%, respectively.

At the trader, coffee beans are infected with *A. niger* and *A. ochraceus* fungi as much as 46%. At the exporter level, 78% of coffee beans are infected by *A. niger*, and 56% of coffee beans are infected by *A. ochraceus*. Sari et al. (2020) reported that as much as 90% of coffee from farmers and collectors are infected by *A. niger*, and about 30% are infected as coffee grounds. *A. ochraceus* infects 10% of coffee beans from farmers, and about 30% infects coffee grounds. This condition occurs when the moisture of coffee beans from farmers are 13.9%, from collectors are 13.45%, from processors are 2.97%, and from exporters range from 9.7 - 10.9%. This study aimed to determine the species of post-harvest fungi that attack Arabica coffee beans, infection rates, and quality of Arabica coffee beans in West Sumatra Province.

Methods

This research was conducted from June 2021 to August 2021 at the Phytopathology Laboratory, Plant Protection Department, and the Seed Technology Laboratory, Agronomy Department, Faculty of Agriculture, Universitas Andalas, Padang, Indonesia.

The research was carried out using a survey and taking samples in the field in a stratified sampling. The method used to identify the post-harvest fungi is the blotter test, which is then compared with Singh et al. (1991) and Watanabe (2002).

Sampling

The areas chosen for sampling are the three highest arabica coffee-producing regions in West Sumatra based on statistical data from the West Sumatra Plantation Service (2019), namely Solok Selatan, Pesisir Selatan, and Lima Puluh Kota. The Solok Radjo cooperative located in Solok District was selected as comparison. This cooperative was chosen because it has received many awards as the preferred coffee bean-producing cooperative, has already processed its coffee beans to become coffee products, and already has a suitable control mechanism for the quality of the coffee beans.

Determination of sampling was carried out following the reference of SNI 19-0428-1998 (Table 1). In each district, samples were taken from three collecting traders to obtain nine samples and the Solok Radjo. The requirements collectors selected as the sampling sites are traders who store at least five sacks of Arabica coffee beans. In each storage area, 1 kg of Arabica coffee beans was taken and then brought to the laboratory.

Tabel 1. Sampling of Arabika coffee beans (SNI, 1998)

Number of samples per lot (sack/crate)	Number of samples taken (sack/crate)
s/d 10	All samples
11-25	5
26-50	7
51-100	10
>100	$\sqrt[2]{\text{samples}}$

Detection of post-harvest fungi

Detection of post-harvest fungi using Blotter Test. One hundred samples of Arabica coffee beans were taken from each collector. The seeds were sterilized with 1% NaOCl for 2 minutes and then rinsed with sterile distilled water. Three sheets of filter paper were moistened and placed in a petri dish. The sterilized coffee beans were placed in 20 petridishes with five beans per petri dish using tweezers, then incubated for seven days in the ADL (Artificial Daylight) room.

Parameter Observed

Identification of post-harvest fungi

The types of fungi that attack Arabica coffee beans were identified macroscopically and microscopically using stereo and compound microscopes. Identification was carried out by observing the color of the colonies of each fungus growing on the surface of the Arabica coffee beans. The parts observed were the stipe, vesicle, conidia, metula, and fialid. The results were compared with Singh et al. (1991) and Watanabe (2002).

Post-harvest fungal infection rates

Seeds infected by all fungi were calculated using the following formula:

$$P = \frac{n}{N} \times 100\ \% \qquad \text{(1)}$$

Where P = Percentage of seeds infected by fungus, n = Number of seeds infected by fungus, N = Number of seeds tested.

Seeds infected by each fungus were calculated using the following formula:

$$C = \frac{a}{b} \times 100\% \qquad \text{(2)}$$

Where P = Percentage of seeds infected by each fungus, n = Number of seeds infected by each fungus, N = Number of seeds tested.

Physical quality

Physical quality measurement refers to the Indonesian National Standard (SNI) by examining the number of defects in coffee beans. Based on SNI (2008), the physical quality requirements of coffee beans are divided into general and special quality. General quality are divided into two stages, the first includes the presence or absence of live insects, foul-smelling seeds, moisture content, excrement, and post-harvest fungi, and the second is to determine the type and number of defective coffee beans (Table 2). The same sample was obtained to test the fungus, weighing 300 grams of coffee beans.

Based on the number of defects, the quality of the seeds is classified concerning SNI 01-2907-2008. The physical quality of coffee beans on farmers are classified as 1-6, the lower the physical quality score, the better quality of the seeds (Table 3).

Water content

Ten grams of sample of coffee beans for fungi test from each collector was taken, put into an aluminum cup, then weighed again. The cup's lid was opened and placed near the cup in the oven. Then the samples were baked at 105°C for 16 hours. After being baked, the cup was closed again and put in a desiccator until the temperature was equal to room temperature and weighed again. The maximum water content value specified by SNI for Arabica coffee beans is 12.50%.

Tabel 2. Determination of the defect value of Arabica coffee beans (SNI, 2008).

Defect type	Score
One black seed	1.0
One partial black seed	0.5
One broken black seed	0.5
One coffee log	1.0
One cocoa bean	0.25
One large coffee skin	1.0
One medium size coffee skin	0.5
One small coffee skin	0.2
One horn-skinned seed	0.5
One large horn skin	0.5
One medium size horn skin	0.2
One small horn skin	0.1
One broken seed	0.2
One young seed	0.2
One seed with one hole	0.1
One seed with more than one hole	0.2
One speckled seed	0.1
One branch, soil/large rock	5.0
One medium-sized twig, soil/rock	2.0
One twig, soil or small rock	1.0

Tabel 3. Quality classification of Arabica coffee beans (SNI, 2008).

Quality	Criteria
Quality 1	Total defects ≤ 11
Quality 2	Total defects = 12-25
Quality 3	Total defects = 26-44
Quality 4	Total defects = 45-80
Quality 5	Total defects = 81-150
Quality 6	Total defects = 151-225

The water content of Arabica coffee beans was determined by the following formula (SNI, 2008):

Water content = $\frac{(m1-m2)}{(m1-m0)}$ x 100%

mo = weight of the cup with the lid (g), m1 = weight of cup with lid and Arabica coffee beans before drying (g), m2 = weight of cup with lid and Arabica coffee beans after drying (g).

Results

Post-harvest Fungi

Based on the identification of this study, the Arabica coffee beans in the Arabica coffee center plantation of West Sumatra Province, Indonesia, were attacked by three species of fungi from genera of Aspergillus, namely *Aspergillus niger, A. Flavus,* dan *A.ochraceus.*

Aspergillus niger

The fungus of *A. niger* found on Arabica coffee beans was black, had hyaline stipe, vesicles had thick walls with a round shape and brown color, and conidia were round, rough, and black in color (Figure 1). Those characteristics were in accordance with *A. niger* based on the book by Singh et al. (1991).

Aspergillus flavus

The fungus of *A. flavus* found on Arabica coffee beans was green in color, has long stipes, hyaline and insulated domed vesicles, and conidia were round and yellowish green in color (Figure 2). These characteristics are in accordance with the fungus of *A. flavus* based on the book by Singh et al. (1991).

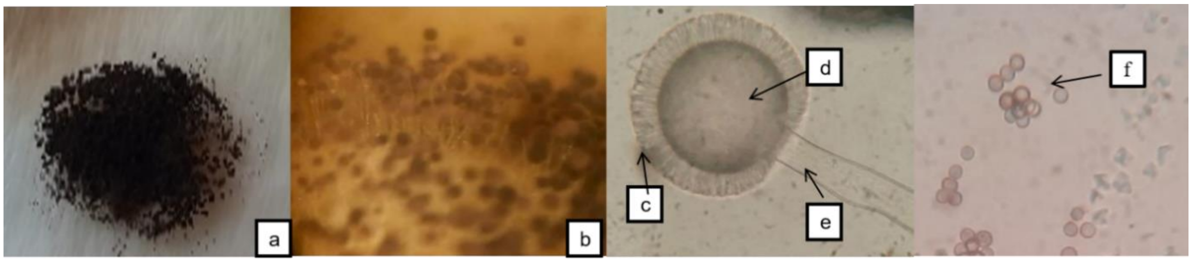

Figure 1. Morphology of *Aspergillus niger*; (a) on the surface of Arabica coffee beans, (b) on the surface of Arabica coffee beans at 40x magnification, (c) fialids, (d) vesicles, (e) stipe, and (f) conidia at 400x magnification

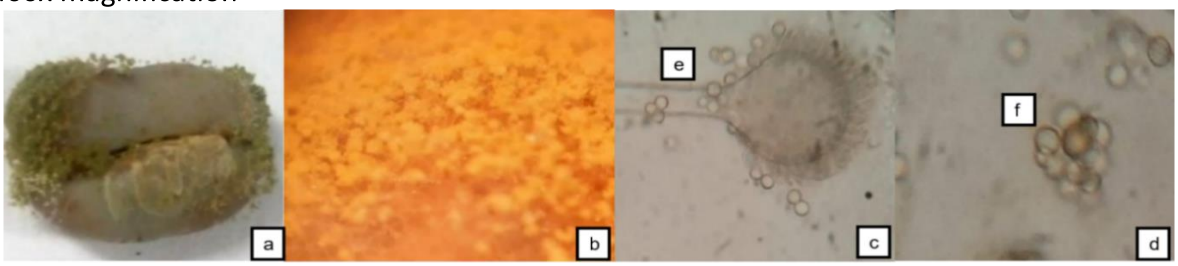

Figure 2. Morphology of *Aspergillus flavus*; (a) on the surface of Arabica coffee beans, (b) on the surface of Arabica coffee beans at 40x magnification, (c) stipe, (d) fialids, (e) vesicles, and (f) conidia at 400x magnification

Aspergillus ochraceus

The fungus of *A. ochraceus* found on Arabica coffee beans was brownish, with long, thick, and rough stipe. Vesicles are round and large, metula long, and fialid short. Conidia were round, small, and smooth (Figure 3). The characteristics are in accordance with the book by Singh et al. (1991).

Infection rate

The highest infection was found in Lima Puluh Kota (63.67%), and the lowest was in Solok Selatan (36%) (Table 4). The highest attack was done by *A. niger* (38.83%) which the most infected in Lima Puluh Kota, and the lowest was *A. flavus* (0.53%) (Table 5). Most damage of beans occurred in the form of cracked seeds (Table 6).

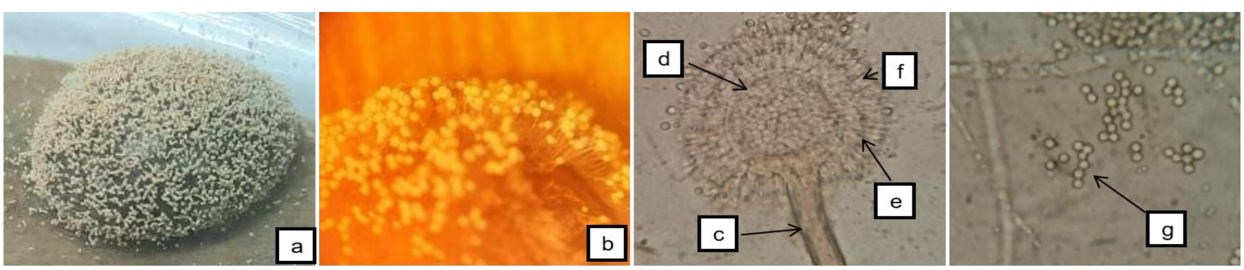

Figure 3. Morphology of *Aspergillus ochraceus*; (a) on the surface of Arabica coffee beans, (b) on the surface of Arabica coffee beans at 40x magnification, (c) stipe, (d) vesicles, (e) metula, (f) fialid, (g) conidia at 400x magnification.

Physical quality

The physical quality of beans varies in each sampling area. The defects found varied with different values (Table 4). From the best quality obtained was 3 and the lowest was 5. The physical quality of Solok Radjo was better than Solok Selatan and Pesisir Selatan but almost the same as Lima Puluh Kota (Table 7).

Tabel 4. Post-harvest fungal infection rates of Arabica coffee beans in Arabica coffee center areas in West Sumatra

District	Attacks (%)			Average (%)
	PP1	PP2	PP3	
Solok Selatan	62.00	28.00	18.00	36.00
Pesisir Selatan	32.00	33.00	46.00	37.00
Lima Puluh Kota	71.00	29.00	91.00	63.67
Solok Radjo	27.00	-	-	27.00

PP = Collector

Tabel 5. Percentage of post-harvest fungal attack on Arabica coffee beans in production centers in West Sumatra

District	Attacks (%)		
	A. niger	*A.flavus*	*A. ochraceus*
Solok Selatan	31.33	0.44	6.00
Pesisir Selatan	35.00	0.66	2.67
Lima Puluh Kota	63.00	0.00	1.66
Solok Radjo	26.00	1.00	6.00
Average	38.83	0.53	4.08

Tabel 6. Total of Arabica coffee bean defects in Arabica coffee center areas in West Sumatra

Defect type	Score/District									
	Solok selatan			Pesisir Selatan			Lima Puluh Kota			Solok Radjo
	PP1	PP2	PP3	PP1	PP2	PP3	PP1	PP2	PP3	PP1
Black seeds	8.0	31.0	23.0	55.0	3.0	4.0	4.0	9.0	20.0	5.0
Black seeds a half	3.5	1.5	-	-	1.0	-	1.5	1.5	6.5	-
The broken black seed	-	1.0	-	-	-	-	-	-	-	-
Coffee logs	-	-	-	1.0	-	-	-	-	1.0	2.0
Brownish bean	-	0.75	3.25	0.5	-	0.25	-	-	-	0.75
1 medium size coffee skin	-	-	3.4	-	-	-	-	-	-	-
1 small coffee skin	-	2.4	-	3.8	0.2	-	0.2	0.6	0.6	1.6
1 horn-skinned seeds	-	0.5	-	-	0.5	0.5	-	-	0.5	4.0
1 large horn skin	-	2.5	-	0.5	-	-	-	-	-	0.5
1 medium size horn skin	-	-	0.2	-	-	-	-	-	-	1.6
1 small horn skin	-	-	0.7	0.1	0.5	-	0.5	0.3	0.1	1.8
Cracked seeds	46.2	11.8	28.4	29.4	45.6	42.2	18.8	18	21.6	9.6
One hole seed	3.4	5	4.4	3.7	1	0.8	3.2	2.8	14.5	0.9
More than one hole seed	1.2	3.2	5.8	3.4	1.4	0.2	4.2	4	16.8	1.0
Total	62.3	59.65	69.15	97.4	53.2	47.95	32.4	36.2	81.6	28.75

PP = Collector

Table 7. Physical quality of Arabica coffee beans at West Sumatra Arabica coffee centers.

District	Quality		
	PP1	PP2	PP3
Solok Selatan	4	4	4
Pesisir Selatan	5	4	4
Lima Puluh Kota	3	3	5
Solok Radjo	3	-	-

PP = Collector

Water content

The water content of Arabica coffee beans found from all sampling locations complies with the limits set by SNI (2008), which was in the range of 10.87 – 12.23% (Table 8).

Table 8. Water content of Arabica coffee beans in production centers in West Sumatra

District	Water content (%)			Average
	PP1	PP2	PP3	
Solok Selatan	11.30	10.70	10.60	10.87
Pesisir Selatan	10.70	12.50	13.30	12.17
Lima Puluh Kota	12.00	11.90	12.80	12.23
Solok Radjo	11.90	-	-	11.90

PP = Collector

Discussion

Based on the identification, the post-harvest fungus that attacks Arabica coffee beans in West Sumatra production centers comes from the Aspergillus, which consists of 3 species, namely *Aspergillus niger*, *A. flavus*, and *A. ochraceus* (Figures 2, 3, 4). This fungus is thought to have spread widely and was widely found in Arabica coffee-growing areas in West Sumatra. Watanabe (2002) stated that Aspergillus can live in any soil but generally grows in tropical climates and around plant roots. The Aspergillus fungus is found in Arabica coffee beans presumably because this fungus has a wide distribution area, is very easy to spread, and the environ-ment is suitable.

According to Lilia et al. (2021), Asper-gillus is a fungus that is widespread and quickly spreads because the wind easily carries its spores. According to Barnet and Hunter (1998), Aspergillus can grow and develop in stored grains, having the ability to grow under conditions of severe physiological drought. Some of these fungal spores are suspected of contaminating coffee beans before roasting and can survive the roasting process, so Aspergillus is still found in processed coffee products. Accordance with Kusumaningrum's report (2019), *A. niger* and *A. flavus* in several coffee grounds after roasting samples.

The Aspergillus with the highest attack was *A. niger*. This fungus was also the most infecting Arabica coffee beans in Lima Puluh Kota. Then, the fungus with the lowest attack was *A. flavus*; it did not find in Lima Puluh Kota (Table 4, Table 5). However, the lowest infection rate was found in coffee beans in the Solok Radjo (Table 4). The high infection rate of *A. niger* is suspected caused by the fungus is easy to grow, the environmental conditions are favorable, and the nutritional content of Arabica coffee is suitable for the growth of this fungus. According to Putri (2019), fungus growth is influenced by the substrate; fungi can grow and develop well on suitable substrates, such as the suitability of fat, protein, and other chemical compositions. Lilia et al. (2021) reported that the common post-harvest fungus in coffee beans is *A. niger*. Dharmaputra et al. (1999), who tested the level of fungal attack on coffee beans collected from traders in Lampung Province, also reported *A. niger* as the dominant fungus (46%). Furthermore, Yani (2008) stated that *A. niger* infects 100% of coffee beans during primary processing.

The method of harvesting, processing, transporting, and storing carries the risk of contamination with microorganisms that can damage coffee beans. The high fungal infection rate in Lima Puluh Kota District is thought to be due to the storage time of the coffee beans exceeding two weeks, as well as the storage environment that supports the growth of the fungus. Dharmaputra et al. (2019) stated that the factors affecting fungal infection are water activity, storage tempera-ture, oxygen, carbon dioxide gas tension, hydrogen ion concen-tration, nutrient content, and preservatives. The drying process and bedding that is not clean and repeatedly used for drying are also suspected as factors for fungal attack. The interviews found that most of the collector used plastic tarpaulin mats as a base for drying the coffee beans. According to Lilia et al. (2021), the drying process affects the susceptibility of the seeds to be penetra-ted by fungi, which causes a risk of decreased physical quality and defects.

Fungus contaminants can occur on mats used repeatedly for drying without being washed. The low infection rate in Solok Radjo is suspected because the cooperative did not store it for a short time, around 2-3 days, and did better post-harvest handling, such as harvesting ripe fruit, sorting the fruit, and processing the coffee cherries themselves so that it was easier to control quality.

The physical quality of Arabica coffee beans from Solok Radjo was better than Solok Selatan and Pesisir Selatan but almost the same as Lima Puluh Kota (Table 7), while the water content from all sampling was in accordance with the limits set by SNI (2008), which was in the range of 10.87 – 12.23% (Table 8). The quality of coffee beans from Solok Radjo was classified as quality 3, with a lower defect than coffee beans from collectors. This is presumably because Solok Radjo processes the coffee beans themselves from fruit to coffee beans that they can control the coffee beans' quality. The low quality was due to the large number of damaged coffee beans dominated by broken seeds. A large number of cracked seeds is thought to occur due to the imperfect peeling process. Winarno and Indah (2020) stated that the quality of coffee beans in Simalungun District, North Sumatra Province varies; quality 2 - 6.

The black seed defects found included whole black seed defects, partial black seeds, and broken black seeds, which were thought to have occurred due to improper processing. This is in accordance with the opinion of Winarno and Indah (2020), stating that black seeds occur due to processing and attack by powdery mildew, which causes the seed to appear reddish yellow like ripe fruit, but after processing, black seed defects occur. Defects in cocoa beans were found to occur due to an improper drying process; this is related to different water content levels.

Winarno and Indah (2020) stated that brown seeds generally occur due to improper drying or too-ripe seeds. The varying water content of the seeds causes an incomplete drying process resulting in brown bean defects. An insect causes seeds with one hole and more than one hole. According to Dharmaputra et al. (1999), during storage, coffee beans can be affected by insects, mites, microorganisms, and rodents; insect pests are considered to be the most significant cause of losses. However, when the observation was carried out, no insect pests were found.

Coffee logs are dried coffee beans still wrapped in compound skins. Coffee logs were found to occur due to an imperfect peeling process which caused some of the beans not to be peeled. This imperfect peeling process is assumed to cause defects in broken beans, coffee skins, horn skins, and broken beans. Winarno and Indah (2020) stated that defects in broken seeds, seed spindles, and horn skin seeds occur during the huller peeling process because the process does not work perfectly.

Conclusion

Based on the study, the types of post-harvest fungi that attack Arabica coffee beans in West Sumatra belong to the Aspergillus genus; *Aspergillus niger*, *A. flavus*, and *A. ochraceus*. The highest post-harvest fungi attack came from Lima Puluh Kota (63.67%), and the lowest was Solok Radjo coffee (27%). The fungus with the highest infection rate was *A. niger* (38.83%), and the lowest was A. *flavus* (0.53%). The best quality Arabica coffee beans are found in Solok Radjo (3), with water content that meets SNI standards.

Declaration

Author contribution

Azis Fauzi is the main contributor of this paper, and Martinius is the corresponding author. All authors read and approved the final paper.

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Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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