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Postharvest spoilage pathogen associated with turmeric (*Curcuma longa* L.) product in Southwestern Ethiopia

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A B S T R A C T

The primary reason for postharvest deterioration, which is primarily brought on by fungal invasion, is the loss of turmeric products in Southwestern Ethiopia. The study was conducted to determine the main fungi responsible for the postharvest deterioration of turmeric in major turmeric-growing areas of southwestern Ethiopia. In total, 60 samples of dried and stored turmeric were gathered in 2020 and 2021 from different production zones of southwestern Ethiopia. The fungus that causes postharvest turmeric to deteriorate was isolated and identified at the genus level. At the study locations, rhizomes were not cleaned, washed, sorted, or separated from healthy rhizomes. The spoiled turmeric samples contain fungi from four genera: Aspergillus, Penicillium, Fusarium, and Rhizopus. Aspergillus, Penicillium, and Fusarium were isolated from drying and storage samples in all zones. However, Rhizopus was only isolated from samples that had been stored. It was discovered that Aspergillus, Penicillium, and Fusarium were primarily responsible for the observed deterioration. The identified genera's percentage incidence ranged from 15.1% (Fusarium) to 45.2% (Aspergillus). Proper harvesting, postharvest handling procedures, and adopting suitable turmeric harvesting and postharvest handling technology can help decrease turmeric postharvest degradation.

Keywords: Fungi, Pathogen, Postharvest, Spoilage, Turmeric

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Introduction

Turmeric (*Curcuma longa* L.) is one of the important spices primarily grown by smallholder subsistence farmers in the southwest of Ethiopia. It brought up a significant amount of smallholders' revenue and provided an excellent potential to diversify the current Arabica coffee-based farming system of southwestern Ethiopia. The agroecology of this area is ideal for the cultivation of turmeric. It is likely to become a cash crop with a significant economic return, especially for farmers with little resources, as commercial production of it in Ethiopia is expected to increase. Additionally, it has been commercialized in significant government investment projects and large-scale private farms, demonstrating the crop's promising future in Ethiopia (Derese, 2009; Masresha, 2010).

Turmeric is a common ingredient in many Ethiopian dishes (Edossa, 1998; Girma *et al.*, 2008). It is utilized in cosmetics and pharmaceutical preparations, has a distinctive flavor, and is antibacterial and anti-inflammatory (Kifelew *et al.*, 2018). On a dry weight basis, the rhizomes were rich in curcuminoids pigments (6.00%) and essential oils (5.00%), as well as 69.43% carbohydrates, 6.30% protein, 3.50% minerals, and other significant components (Olojede *et al.*, 2005). Additionally, it serves as a coloring agent in various food and beverage preparations. Turmeric color extracts are also used to manufacture soap, cosmetics, and pharmaceutical products (Purseglove *et al.*, 1981; Girma *et al.*, 2008). Turmeric is mainly grown in Ethiopia's southwestern region (Sheka, Bench Sheko, and Keffa zones). Turmeric, a tropical plant, grows well between sea level to 1500 m above it, with temperatures between 20 and 35°C and an average annual rainfall of at least 1500 mm. Even though it can be cultivated in various soil types, it flourishes in sandy or clay loam soils with adequate organic matter status and a pH range of 4.5 to 7.5 (Jayashree *et al.*, 2015).

Numerous fungal infections, both airborne and soil-borne, can affect turmeric. Viral and bacterial diseases are rare. The major diseases affecting the crop are rhizome rot, leaf spot, leaf blotch, leaf blast, and leaf blight (Ravindran *et al*., 2007). Other problems include nematode infestations and storage rots. Numerous fungi and other organisms have been reported in various turmeric-growing areas associated with the disease (Anandam *et al*., 2019; Reddy *et al*., 2003). Additionally, postharvest losses of turmeric were caused by numerous bacterial and fungal species. Some of these include the genera of Penicillium (soft rot and blue mold), Fusarium (dry rot), Rhizopus (watery rot), Armillaria (Armillaria rot), Sclerotium (rhizome rot), Pythium (cottony-watery rot), Stachybotrys (soft rot), Erwinia (soft rot), and Pseudomonas (rhizome wilt) (Cherian, 2002; Dohroo, 2005).

Although turmeric is a crop with many uses, the quality of the rhizome influences the crop's establishment, growth, yield, and the growers' financial return. This multipurpose crop frequently spoils and loses quality due to microorganisms that result in rhizome product loss. Although attempts have been made to conduct studies on the agronomic features and chemical components of turmeric grown in Ethiopia, no work has been done on the microorganisms that cause turmeric to spoil in Ethiopia. Thus, this study was planned with the following objective:

- To identify the main fungi responsible for the diseases and postharvest deterioration of turmeric products.

Materials and Methods

Samples of turmeric were collected from the Mejang zone of the Gambella regional state, Sheka and Benchi sheko zones of southwestern Ethiopia people's regional state. The main harvesting seasons of 2020 and 2021 were used for the postharvest field survey and sample collection. The survey is aimed to know about local traditions for turmeric harvesting, drying, and storage and their knowledge of microbiological postharvest deterioration. Various retailers in all zones were also visited to observe storage conditions. The closed-ended questionnaire was designed to identify problems associated with traditional methods of harvesting, transporting to markets, drying, and storing turmeric, and to know more about the postharvest microbial deterioration of the spice.

The sample collection

From all zones, 60 turmeric rhizome samples weighing 250 and 500 g were collected and brought to the plant pathology laboratory at the Tepi Agricultural Research Center, Ethiopia. Purposive sampling was used, and the samples were composed of rotting rhizomes (those that had developed rot, discolored, or had fungal growth) and some healthy rhizomes. Twenty-five samples of dried turmeric (15 from Sheka, 5 from Benchi sheko, and 5 from Mejang) and thirty-five samples (20 from Skeka, 5 from Benchi sheko, and 10 from Mejang zone) of dried turmeric that had been preserved were used. For samples that were dried by the sun, turmeric rhizomes that had been left out in the sun for 5 to 15 days were used, and for samples that were dried and stored, turmeric rhizomes that had been stored for 5 months to a year were used.

Isolation and identification of the pathogen

Samples of turmeric rhizome (250 to 500 g) were cleaned with sterile distilled water, surface sterilized for 3 to 5 minutes with 1% sodium hypochlorite, and then cleaned three times more with sterile distilled water. The samples were then crushed using a clean mortar and pestle. 250 g of powder and 250 ml of sterile, distilled water were mixed to form the slurry. Using a micropipette, 0.1 ml of the slurry was spread on pre-dried, sterile Potato Dextrose Agar after being thoroughly mixed. The plates were incubated for 4–7 days at 25°C. When the mycelia emerged, the organisms were subcultured onto fresh, sterile potato dextrose agar media to obtain a pure culture of each isolate. Using a sterile inoculating needle, seven to fifteen-day-old fungal cultures grown on Potato Dextrose Agar were aseptically removed, placed separately on clean microscopic slides, and dyed with cotton blue (aniline blue) (1 g in 1000 ml distilled water). Fungi were identified to the genera level based on morphological features using a compound microscope and colony characteristics on Potato Dextrose Agar compared with structures in Crous *et al.* (2009). According to Aboagye-Nuamah *et al.* (2005), the percentage occurrence of each identified genera was calculated as a percentage of all samples:

$$\text{PI}\ (\%) = \frac{\text{NTG}}{\text{TNI}} \text{X}100$$

Where,

TNI = total number of isolates, NTG = number of times the genera were isolated, and
PI = percentage incidence of the genera

Results and Discussion

In all zones, turmeric is harvested by loosening the soil around the plant's crown by digging around the rhizome using a fork, spade, or hoe. Farmers have been observed to put boiled turmeric onto the dirty ground, which promotes the formation of mold and further accelerates deterioration during sun drying. The survey also revealed that cleaning and washing are not common at all sites before boiling turmeric. The survey also revealed that most respondents did not distinguish between healthy and damaged rhizomes or finger and mother rhizomes when boiling and drying rhizomes. All respondents dried their turmeric on contaminated soil by exposing it to sunlight. Most turmeric farmers always store their dried crops on the ground in sacks. The survey also revealed that spoiled turmeric has similar characteristics throughout all districts. All respondents knew the traits of spoiled turmeric. Among the signs of rotten turmeric are rhizomes covered in mold, rhizomes that have rotted in damaged or broken areas, rhizomes that possess a pungent smell, etc.

Fungal diversity on drying turmeric

Fungal diversity from sun-drying turmeric samples in Sheka, Benchi sheko and Mejang is presented (Table 1). The fungal diversity in the stored turmeric samples was high at all locations. Rhizopus was not isolated from turmeric sample drying in the sun at any sites.

Table 1. Sample type and fungal diversity at Sheka, Benchi Sheko, and Mejang zone.

Location	Sample type	Number of samples	Fungal diversity
Sheka	Sun drying	15	Aspergillus, Fusarium, Penicillium
	Stored	20	Aspergillus, Fusarium, Penicillium, Rhizopus
Benchi Sheko	Sun drying	5	Aspergillus, Fusarium, Penicillium
	Stored	5	Aspergillus, Fusarium, Penicillium
Mejang	Sun drying	5	Aspergillus, Fusarium, Penicillium
	Stored	10	Aspergillus, Fusarium, Penicillium, Rhizopus

Since less hygienic operations were used (as mentioned in this survey) during turmeric drying, as shown in sample collection seasons, it is expected to obtain such a high fungus load and diversity (Table 1). The survey also revealed that the rhizomes of turmeric were exposed to the sun on unclean ground (soil).

Occurrence of fungi

Four fungal genera were isolated and associated with the postharvest spoiling of turmeric from Sheka, Benchi Sheko, and Mejang zone.

Table 2. Fungi that were identified when turmeric was dried and stored in the Skeka, Benchi Sheko, and Mejang zones.

Fungal genera	Sheka		Benchi Sheko		Mejang	
	Drying turmeric	Stored turmeric	Drying turmeric	Stored turmeric	Drying turmeric	Stored turmeric
Aspergillus	+	+	+	+	+	+
Fusarium	+	+	+	+	+	+
Penicillium	+	+	+	+	+	+
Rhizopus	-	+	-	-	-	+
Total	3	4	3	3	3	4

Notably: + Presence of corresponding fungi genera in the sample, - Absence of corresponding fungi genera in the sample.

From all locations, Fusarium, Penicillium, and Aspergillus genera are isolated from both drying and stored turmeric samples (Table 3). In contrast, Rhizopus was isolated only from stored turmeric samples at Sheka and Mejang zone. The genera of fungal organisms, i.e., Aspergillus, Fusarium, Penicillium, and Rhizopus, were identified in this study. During drying and storage at study sites, the postharvest deterioration of turmeric rhizomes was associated with these fungus species. Further, the results revealed that Aspergillus was the main factor in the deterioration of turmeric during drying and storage. This could be explained by Aspergillus being a storage fungus (NARI, 2004) since no washing or other method was used to remove the dirt from the rhizome surfaces.

The mechanisms used to harvest and dry the turmeric at the study sites may have made it easier for spoilage fungi to enter the rhizomes through natural openings, damages, and injuries. At study locations, it was seen that turmeric was not cured, allowing the skin to thicken and the cut ends to suberize. It was widely known that the main causes of turmeric spoiling were wounds and damage during harvesting and postharvest handling procedures (Yiljep *et al.*, 2005). If not properly dried, the damaged, injured, and cut ends of the turmeric rhizome may act as a starting point for the pathogenic and deteriorating fungus that can spread to the stock and facilitate spoiling and deterioration. The survey's findings also revealed that growers and traders at the study sites dry turmeric by leaving it in the sun on contaminated soil for a longer period (3 weeks and above). Long-term sun exposure to boiled turmeric may result in rapid water loss and shrivelling, leading to cracks that could be entryways for spoilage and pathogenic fungi. Prolonged drying on such unclean ground would also create an environment favorable for various fungal growths, which could facilitate the development of spoilage and rot.

Percentage incidence of fungi

The percentage incidences of postharvest spoilage fungi isolated from spoiled turmeric vary during drying and stored turmeric samples (Fig. 1).

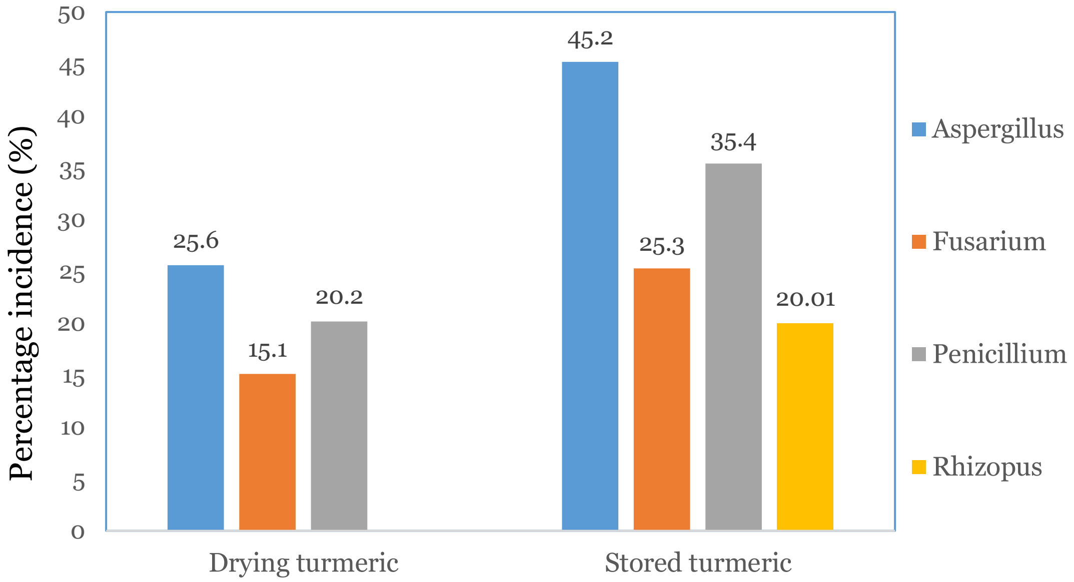

Fig. 1. Sampling categories.

Fungi were more likely to grow on damaged turmeric rhizomes in percentages ranging from 15.1% (Fusarium) to 45.2% (Aspergillus). Aspergillus was responsible for 25.6% of the spoilage under drying conditions, followed by Penicillium (20.2%) and Fusarium (15.1%) (Fig. 1). In a similar vein, Aspergillus and Penicillium were mostly responsible for the storage-related deterioration of turmeric. Aspergillus and Penicillium comprise 45.2% and 35.4% of the stored turmeric samples. Rhizopus was also identified as the cause behind the deterioration of the turmeric during storage. Fungal load and variety increased during storage. Diverse fungus groups were responsible for the deterioration of stored turmeric at all locations. Increased fungal load and diversity may be related to the sample sites' high relative humidity, above-average moisture content, and long-term storage of the product.

The results showed that Aspergillus was among the most common postharvest degrading fungi throughout drying and storage. Aspergillus is a well-known storage fungus commonly linked to high relative humidity and requires moisture condensation on the rhizome surface (Adams and Moss, 2000; FAO, 2004). At storage, Rhizopus was isolated. It is generally known that Rhizopus is a wound pathogen and an ineffective colonizer of healthy rhizomes (NARI, 2004). Rhizopus isolation during storage may suggest that some damaged and injured rhizomes during harvest and drying were infected by Rhizopus, most likely through the soil and other sources. In line with this finding, Cherian (2002) and Dohroo (2005) also found that Aspergillus, Penicillium, and Fusarium cause postharvest deterioration. Studies showed that these fungal species were responsible for the deterioration of many agricultural products at storage. Therefore, to minimize turmeric postharvest deterioration, future studies should be planned on proper harvesting and postharvest handling activities to reduce postharvest deterioration of turmeric products.

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