World Journal of Agricultural Sciences 18 (4): 200-205, 2022
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2022.200.205

Assessing Pepper Storage Methods and Factors of Postharvest Losses in Major Producing Areas of Ethiopia

Negasa Fufa

Ethiopian Institute of Agricultural Research,
Ambo Agricultural Research Center, P.O. Box: 37, Ambo, Ethiopia

Abstract: The study aimed to assess the storage methods and factors of fungal growth in stored pepper. The assessment was done diagonally apart from 10m of each farmer to get different storage methods and storage practices. Structured questionnaires were directed to obtain primary information from farmers, retailers and wholesalers. The collected data was analyzed using SPSS package software (version 26.0). The mean percentage was separated by simple descriptive statistics. The majority of the farmers, 87% (n = 80) harvest the peppers green, red and fully red by hand picking, but 13% (n = 80) are sickled with the stem. 89% (n = 80) of the farmers dry their peppers on bare ground, mat, or heap few of them hanging on the trees and a few of them dry the pepper on the roof. 5 to 10% of the produce was lost at the field and on the drying site due to leftover and miss management of the farmers. 90% of farmers, retailers and wholesalers stored the pepper in the sack and a few 10% stored in gotra, floor and stalk with the stem. From this study, it was concluded that harvesting and drying, inoculum source, use of water to increase weight at retailers and wholesalers and ways of storage by farmers, retailers and wholesalers favor the development of mycotoxigenic fungi.

Key words: Storage Fungi · Harvesting · *Capsicum* annum · Waste · Postharvest Loss

INTRODUCTION

Hot pepper (*Capsicum annum* L.) is native to Latin America and belongs to the family Solanaceae [1]. Pepper is the most commonly produced spice [2-5] and accounts for over 80% of total spice produced in the country [6]. The exact time of pepper's introduction to Africa in general and Ethiopia, in particular, is not known. Probably the Portuguese introduced hot pepper to Ethiopia in the early 17th century [7]. In Ethiopia, hot pepper is one of the cash crops for smallholder farmers and contributes to export earnings [8]. The nutritional value of hot pepper merits special attention. It is a rich source of vitamin A and E and contains five to six times as much vitamin C as an orange or lemon; this makes it an ideal vegetable to prevent flu colds more than any other vegetable crop [9]. In Ethiopia, the average dry and green hot pepper production is 1.6 t/ha and 10.7 t/ha, respectively [10], which is far below the world's average. In 2018, the total area used for the cultivation of green and red pepper in Ethiopia was 152, 7523 ha with an estimated total production of 2, 647, 22.5 t. Interestingly, this data shows that hot pepper covers 73.1% of all the area under vegetables in Ethiopia [11]. Despite their importance, peppers are susceptible to fungal infection and mycotoxin contamination. In the field, the phyllosphere of the growing plants is mainly colonized by yeast and by the filamentous fungal genera Alternaria, Fusarium, Cladosporium and Rhizopus. In the harvesting and post-harvest phases, including drying and subsequent product transportation, Aspergillus and Penicillium species are the predominant contaminants [12, 13]. Mycotoxins are heat stable and difficult to remove once present in the Capsicum pepper production chain.

Previous studies have shown that industrially processed Capsicum products can be contaminated with aflatoxins (AFs), ochratoxin A (OTA), fumonisins (FBs), zearalenone (ZEN), trichothecenes (TCT's) and patulin (PAT) [14]. These mycotoxins can trigger several acute and chronic diseases and, in more serious cases, can result in fatal consequences (e.g., most recently in Tanzania in 2016) [15]. Liu *et al*. [16] reported that about 40% of liver cancer incidences in Africa have been attributed to dietary AFs exposure. Poor harvesting

Corresponding Author: Negasa Fufa, Ethiopian Institute of Agricultural Research,
Ambo Agricultural Research Center, P.O. Box: 37, Ambo, Ethiopia.

practices, improper drying, handling, packaging, storage and transport conditions contribute to fungal growth and increase the risk of mycotoxin production. The major factors that contribute to the significant impact of mycotoxins in Africa have been identified as climate change [17], lack of awareness, poor agricultural practices and pre-and post-harvest management [18]. In addition, the unavailability of modern infrastructures such as drying and storage facilities [19] as well as inadequate marketing and transportation systems has intensified the effects of these factors.

Peppers are commodities of economic relevance that are used in different gastronomic cultures. However, there is still a lack of information, especially on the fungus-mycotoxin-Capsicum pepper relationship [20], which also contributes to widespread fungus contamination in several crops in Africa. Therefore, the objective of this study is: - To assess fungus methods used and factors of fungus growth in pepper.

MATERIALS AND METHODS

Survey Areas and Sampling Methods: The assessment was conducted at Bambasi, Dabo Hana, Jima Arjo, Wayu Tuka, Sibu Sire, Gobu Sayo, Bako, Ilugelan, Bure, Mankusa, Silkamba, Nono, Marako and Alaba districts of Ethiopia based on their production potential together with woreda agricultural experts to understand farmers views on the fungus contamination of peppers under storage conditions. Structured questionnaires were directed through personal interviews to obtain primary and other information from farmers, retailers and wholesalers. The assessment was done diagonally apart from 10m of each farmer to get different storage methods and storage practices. During the assessment, three kebele were selected from each woreda and from each kebele, three farmers were selected based on the production potential. The data like post-harvest losses due to improper storage methods and diseased and moulded peppers were observed in the farmers, retailers and wholesalers' storage.

Statistical Analysis: The collected data were analyzed using SPSS package software (version 26.0) and the mean percentage was separated by simple descriptive statistics.

RESULTS AND DISCUSSIONS

Harvesting Piking Sickling: Figure 1 indicates the field observation and harvesting methods of farmers in the survey areas. 87% (n = 80) of the interviewed farmers harvest their peppers in the green, red and fully red stage using hand picking but 13% (n = 80) of the sickled with the stem. During harvesting, the farmers harvest diseased pods without sorting and/or removing them and this favors the growth and development of fungus during storage. Peppers should be harvested by grasping the fruit in the hand with the thumb and forefinger and pressing against the stem, followed by snapping the fruit off the plant [21]. In the sowing stage, excessive irrigation and fertilizer application above the recommended levels enhance plant susceptibility to fungal colonization [22]. Harvesting of Capsicum fruits takes place at different stages during maturation. For the agroindustry sector, they are usually harvested fully mature [23, 24]. Harvest starts when one or two berries turn yellow. The spikes are nipped off by hand and collected in bags. Normally, a single-pole bamboo ladder is used as a support for harvesting [25]. The whole pepper production chain should be managed carefully to prevent fungal infection and mycotoxin contamination.

Methods of Drying and Post-Harvest Loss Pepper: Farmers around the Bako district, especially in Kedjo kebele, have dried their peppers on the roof of their houses. This causes uneven drying of the product because variations in the temperature are high in the daytime and it gets warm in the afternoon until it is collected from the roof. This causes mild/warmness of the produce and favors the development of moulds. From this improper drying, we visually observed that up to 1-2% loss was recorded due to loading and unloading. Almost all of the interviewed farmers, 89% (n = 80), dried their peppers on bare ground, a mat, or heap and a few of them hung on the trees and up to 5% of the produce was lost. About 1% of the loss of the product was due to transportation and loss and wholesalers reached up to 5-10% due to adding water to increase the weight of the produce. FIA [26] reports to obtain an even drying, the pepper pods are usually smoked after being placed on the floor and turned several times. Moreover, in other countries, depending on the weather, sun-drying takes between 14 and 21 days. Overall, during the drying period, pods are affected by changes in temperature, exposure to dust and wind and insect infestation [27]. Ahn *et al*. [28], for pepper samples, polyethylene bags and vacuum-packaging methods have proven to be more efficient for inhibiting water reintroduction and decreasing aeration, both factors that are important for limiting fungal growth and mycotoxin production [29].

Fig. 1: Pepper harvesting/piking methods of farmers in Ethiopia

Fig. 2: Pepper drying methods of farmers in Ethiopia

Fig. 3: Pepper methods of storage at farmers, retailers and wholesaler in Ethiopia

Storage Methods of and Post-Harvest Loss Pepper: The survey results indicate that 90% (n = 80) of the interviewed farmers, retailers and wholesalers stored their pepper pods in the sack and a few, 10% (n = 80) stored in gotra, floor, the sickled stalk with the stem. Laying the stack one over the other, lack of storage sanitation, uncontrolled moisture content and not removing the rotted and moulded pods are the major problems observed in farmers, retailers and wholesalers' storage. In the retailer's and wholesalers' storage, they add water to increase the weight of the product. This favors the growth and development and storage of fungi collected from field inoculum. In a similar study by Mueller *et al*. [30], poor post-harvest hygiene in storehouses can lead to further

Fig. 4: Dissected and grinded diseased pods of pepper

fungal colonization and an increase in the risk of mycotoxin contamination. The source of postharvest outbreaks is not always evident; fruit can be infected directly from inoculum present on neighboring fruit, from latent infections, or at wound sites [31]. In storage, RH levels and atmospheric conditions are largely dependent on the crop being stored and the quantity. Disease severity levels are reduced when storage containers are kept at low O_2 and high CO_2 levels [32]. However, high frequencies of fungi in pepper powder and other seasonings produced with Capsicum have been described in recent years [33]. To avoid fungal infection and mycotoxin contamination in the post-harvest stage, the pepper should be dried to around 13% moisture content [34]. The long periods of drying and poor sanitary conditions where pepper products are stored can contribute to a gradual increase in fungal contamination levels.

Factors for the Development of Fungi in the Stored Pepper: Storage fungi were the most important diseases that reduce the production and reduce export quality of peppers in Ethiopia. From this survey, it was observed that the field disease was an inoculum source during storage. Methods of harvesting, drying and storage practices are also critical factors that contribute to the growth and development of moulds during storage. The farmers harvest diseased and moulded pods without sorting them and they sell them to retailers and wholesalers. In both market chains, they added water to the product to increase the weight for the selling process. This favors the growth and development of microbial agents and aggravates mouldiness until they are sold. The drying methods observed were not appropriate because drying on the bare ground and on the roof favors the development of the fungi during storage. Also, the way farmers, retailers and wholesalers store their produce creates favorable conditions for the development of moulds. For instance, piling several sacks one over the other increases the respiration rate, moisture content and metabolic activities they produce in the storage. This favors the growth and development of mould. Peppers are susceptible to several postharvest diseases, most of which require mechanical damage or weakening of the tissue before they can penetrate the fruit. The waxy skin of peppers offers protection against infection, but it is easily damaged by rough handling. Bacterial and fungal pathogens may also enter the fruit through the severed stem tissue and natural openings around the calyx [35].

CONCLUSION

Pepper is the major produced crop that covers 80% of the total spice produced in Ethiopia. The majority of the interviewed farmers harvest their peppers in green, red and fully red stages using hand picking but few of them are sickled with stem pile. From this study, it was observed that the interviewed farmers dried their peppers on bare ground, mat, or heap, a few of them hanging/piling on the trees and a few of them drying on the roof. A huge percentage of the produce was lost at harvest in the field and during drying due to leftover and missing management by the farmers. The interviewed farmers, retailers and wholesalers stored their pepper in sacks and a few of them were stored in gotra, floor and stalk with the stem. The greatest of the farmers harvest the peppers with diseased pods and after drying they sell them to the retailers and wholesalers. The farmers harvest and dry the collected peppers without sorting with the field inoculum and retailers and wholesalers use water to increase the weight of the product, a critical factor for the growth and development of storage fungi. From this study, it was concluded that pepper production and productivity in Ethiopia require attention from the national

and regional governments since it is the main export vegetable crop for the country. Further, research work must be advocated on the reduction of storage fungi in pepper during storage, for quantity and quality in domestic and export markets and on health aspects of the users.

ACKNOWLEDGMENT

The author is grateful for financial support of this work provided by the Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center.

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