Agritech, 38 (2) 2018, 167-171

Initial Moisture Content of Corncobs Plays an Important Role in Maintaining its Quality during Storage

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Submission: February 13, 2017; Acceptance: May 3, 2018

ABSTRACT

Maize is one of the important staple foods for people in Timor, East Nusa Tenggara Province, Indonesia. Subsistent farmers store the maize for their own consumption until the next harvest season, for seed and feed. However, high initial water content of the kernel due to improper drying prior storage initiate serious damage and losses during the maize storage. High water content promotes the growth of fungi and insects, and increase respiration rate, resulting in rapid deterioration of maize. The purpose of this study was to determine the initial moisture content that might minimize damage and losses of maize in the farmers' storage, and to study the effects of some plant materials that are used to smoke corns before storage. The experiment was initiated by sun-drying the harvested corncobs for 0, 2, 4, 6, 8, and 10 days (6 hours a day). This experiment was designed using Completely Randomized Design with 6 treatments and 3 replications. Dried corncobs were stored in the farmer's storage for 4 months. The effects of maize kernels' initial water content on the development of water content in kernels; the percentage of damaged kernels; and the species of pathogen and insects were investigated during storage with 2-week intervals. The results demonstrated that drying the corncobs prior storage for 10 days, resulting in 12.96% of water content, significantly decreased the percentage of seed damage to 6.5%, as compared to without drying process which resulted in 63%. *Aspergillus flavus*, *Fusarium* sp., and *Penicillium* sp were found to be the main pathogen during storage. There are no insect pests found during the storage.

Keywords: *Aspergillus flavus*; insect pest; maize postharvest; moisture content; percentage of damage

INTRODUCTION

Maize is one of the important staple foods for people in Timor, East Nusa Tenggara Province, Indonesia. It is mainly grown by subsistence farmer for consumption, seed supply and for animal feed. Around 6 percent of total national maize production is produced in East Nusa Tenggara province every year (Chafid, 2015). In 2014, East Nusa Tenggara produced 647,108 ton and increased to 690,710 ton in 2015 with an increase of 6.74 percent (Biro Pusat Statistik NTT, 2015). Maize consumption in East Nusa Tenggara is 39.21 kg/capita/year and it is higher than the national consumption, that is only 28.40 kg/capita/year (Ariani & Pasandaran, 2005).

Despite the steady production of maize over the decades, postharvest losses of maize remained significant, up to 30–40 percent in some rural areas (Suleiman & Rosentrater, 2015). One of the most critical physiological factors in successful grain storage is the moisture content of the crop. High moisture content leads to grain deterioration during storage because it encourages fungal and insect problems, respiration and germination (Gonzales, Armstrong, & Maghirang, 2009; Lawrence & Maier, 2011). Biological and biochemical activities occur only when moisture is present. Hence, for safe storage of grain, both the grain moisture content and the moisture of surrounding air should be reduced and monitored.

Generally, traditional farmers of The East Nusa Tenggara, especially in Timor, store the corn directly after harvest without drying (Mukkun, Picualy, & Tandi Rubak, 2014; (Tuke, 2014). Harvested maize with the husk on is hung over the traditional round home or "umek bubu" until the next growing season (Tuke, 2014). Mukkun *et al.*, (2014) reported that the water content of harvested corn is still high, ranging between 25–35% and is very suitable for the growth of fungi such as *Aspergillus flavus; A. niger; A. fumigatus; Fusarium spp.; Penicillium* spp.*; Rhizopus* spp.*; and Mucor* spp.; as well as insect pests *Sitophylus zeamays.* High water levels is thought to be the major cause of damage to corn in storage, reaching 70.4 percent in Kupang district and 61.11 percent in South Central Timor (Timor Tengah Selatan) district. The quality of the seeds also decreased during storage because of high initial water content (Rashid, Kurt, & Carl, 2013).

DOI: http://doi.org/10.22146/agritech. 26663
ISSN 0216-0455 (Print), ISSN 2527-3825 (Online)

Based on these problems, it is necessary to dry before storage to determine initial water content that can reduce damage and loss of quality during storage of maize cobs by farmers. This study aims to determine the drying time and the initial moisture content that can reduce maize losses during storage. The results of this study can be very useful for the farmers and the governments in reducing losses and improving the quality of maize during storage.

MATERIALS AND METHODS

The study was carried out in a traditional farmer's house in Kuaklalo village, Tunfeu sub-district, Kupang Regency of East Nusa Tenggara (Fig. 1) from April to August 2016. Local white maize used as research material was obtained from the farmer, because it is grown by most farmers in Timor. Freshly harvested maize ears were tied up as many as 10 cobs per bundle, and every bundle of maize was used as an experimental unit (Fig. 2).

The experiment was planned using completely randomized design, with 6 treatments and 4 replications. The different drying time (no drying, 2, 4, 6, 8, and 10 days of drying) were applied to obtained different initial water content of maize. Measurement of water content was made at the end of the drying time and it is considered as the initial moisture content of maize.

The treated maize was stored above a fire place in a farmer's house for 4 months. Corn storage was conducted at the traditional Timorese house known as the *roundhouse* because of its round shape. This house serves as a place for family to do all activities including cooking. A roundhouse measures approximately 15 m^2 in diameter, the floor is made of clay, the walls of timber, and the roof of dried grass. The room temperature depends on the cooking activity in the house, ranging from 25 to 40 °C and humidity is around 50 to 80%. The storage serves as a place to store food stocks such as maize, beans, squash, green beans, as well as storage of seeds for the next planting season.

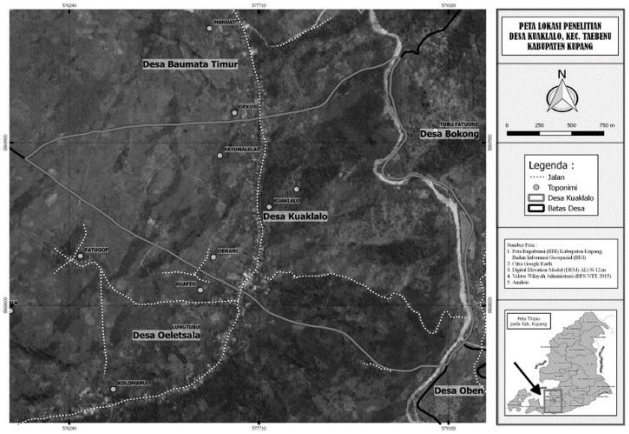

Figure 1. Site plan of the research

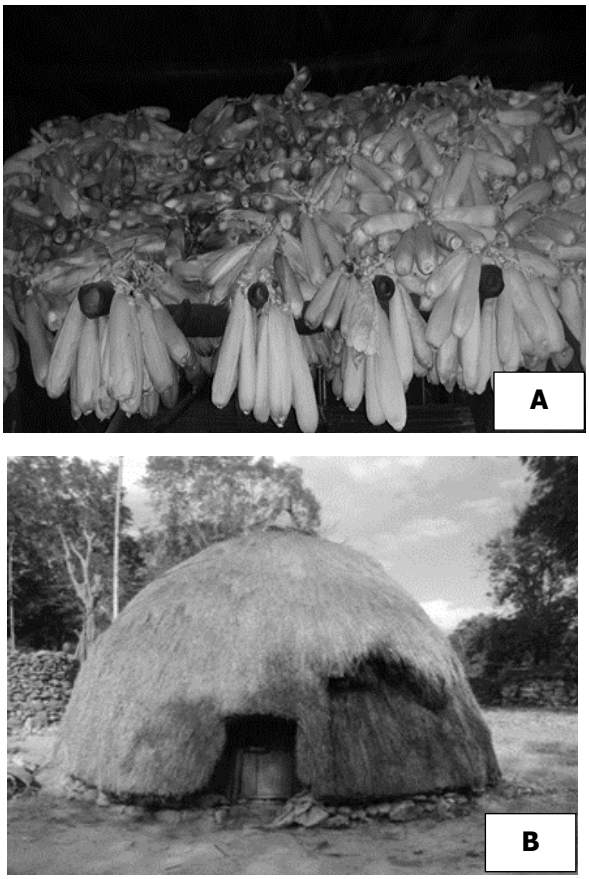

Figure 2. Harvested maize as treatment unit (A), Treated maize were stored in the roundhouse for 4 months

Water Content (%)

Analysis of water content of seeds was analyzed using thermogravimetri method. Corn kernels and Petri dish were weighed, and then heated in an oven with a temperature of 105°C until the seed weight was constant (24 hours). The difference between the initial seed weight and seed weight after drying is calculated as the moisture content on a dry basis (% DM).

Intensity of Seed Damage

Determination of damage percentage: A random sample of 100 grains of each variety was taken from each storage bag using the cone and quarter method. Bored grains were separated from whole grains and their numbers were counted. This was done monthly and repeated three times for each sub-sample and the value of means taken. The damage percentage was calculated using the formula described by Harris & Lindblad, 1978 below

$$\text{Damaged grain} = \frac{\text{number of damaged grain}}{\text{number of total grain}} \times 100 \quad (1)$$

Determination of Insects and Pathogens

To identify the types of pest in the storage, all species of insects were collected and brought to the laboratory

for identification a determination key. Seeds that showed a symptom of fungal attack were collected and cultured in PDA (Potato Dextrose Agar) for identification.

All the data was analyzed with ANOVA followed by Tukey HSD, and $p \leq 0.05$ was considered as a criterion for significance. Simple regression analysis was used to investigate correlation between initial water content and total damage of the maize grain during storage.

RESULTS AND DISCUSSION

Initial Moisture Content

Deterioration of maize is mainly affected by moisture content, temperature (grain and air), relative humidity, storage conditions, fungal growth, and insect pests. Fungal growth, especially *Aspergillus flavus* and *Fusarium sp.* in maize, facilitated by hot and humid conditions, poses a major risk through production of mycotoxins (Rashid *et al.*, 2013). Initial moisture content is determined by drying corn with different drying times before storage. The treatment using different drying times resulted in significantly different initial water contents of the maize before storage (Fig. 3). Maize which is not dried before storage have an average moisture content of 31.28%, while the drying for 10 days reduced moisture content of corn up to 12.96%. Generally, the farmers in Timor Island store maize immediately after harvest without drying; this condition is thought to be the main factor causing damage to corn kernels during storage. Therefore, drying is very important to reduce the moisture level to accepted level of 13.5%. Fig. 3 explains that to achieve optimum water content for storage (12–13%) it needs 8 to 10 days of drying time with 6 hours of drying per day. Conversely with less than 10 days drying, moisture content is still high (> 14%), thus supporting the growth of pests and diseases, as well as physiological processes which cause damage and loss during storage. The species of fungi such as *Aspergillus flavus, A. niger, A. fumigatus, Fusarium* spp*., Penicillium* spp*., Rhizophus* spp*., and Mucor* spp*.* (Table 1) were found in all treatments except the drying treatment of 10 days. It proves that low initial water content of the kernel prevents the development of pathogen-caused damage in the storage.

It is also seen that drying for 10 days causes less damage (6.5%) than with other treatments. Even maize damaged without drying before storage reaches 63%. Mukkun *et al.*, (2014) also reported that the damage and losses during storage of maize is high, could reach 70.4 % in Kupang District, and 61,11% in Timor Tengah Selatan District. Fungi, such as *Aspergillus flavus,* and insects (*Sitophilus zeamais*), are the main cause of damage due to high water content during storage (Firmansyah, Aqil, & Sinuseng, 2010). Hettlarachchi, Gooneratne, & Hirimburegama, (2001) stated that initial water content is a key factor limiting fungal growth in maize grain. Therefore, control of grain moisture content before storage is very important to prevent damage caused by fungi and insects during storage.

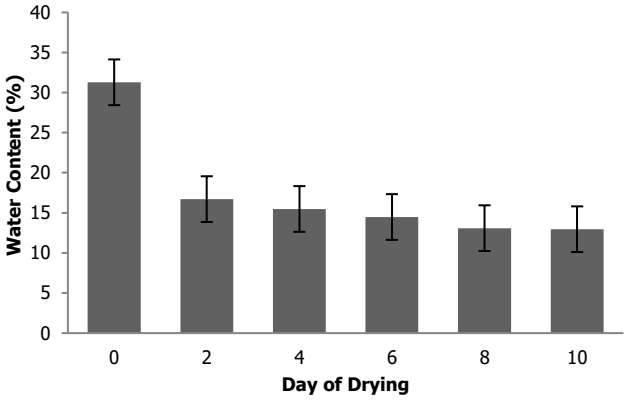

Figure 3. Initial water content of the maize seed after different sun drying times

The Development of Water Content during Storage

As a living material that performs physiological processes, the moisture content of corn will initiate changes during storage. Hygroscopic properties of corn lead to increasing and decreasing moisture content during storage and largely determined by environmental conditions such as temperature and humidity (Seifi & Alimardani, 2010; Rashid *et al.*, 2013). Maize consists of a constant amount of dry matter but water content will vary (Devereau, Myhara, & Anderson, 2002). Moisture content plays a significant role in the storage of grain; when grain has more moisture, it heats up and can have mold spoilage (Brewbaker, 2003). Fig. 4 shows that water content of the seeds decline dramatically in the first 2 weeks of storage, but then there was a fluctuation until the end of storage.

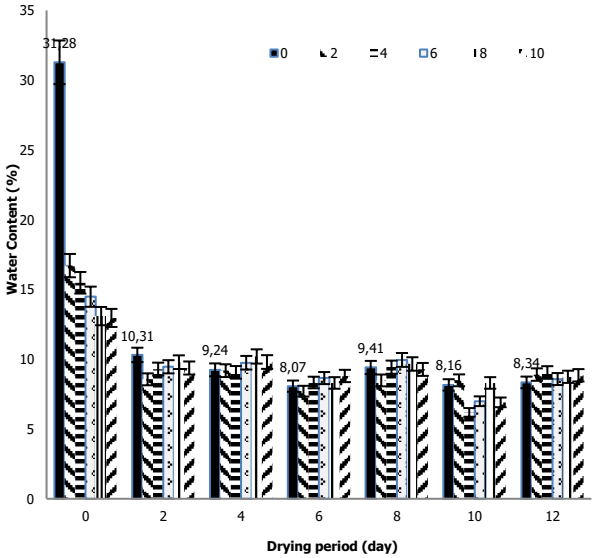

Figure 4. The development of water content of stored maize in Timor traditional storage

Treatment with different drying times significantly affected the moisture changes during storage at $p \leq 0.5$.

The drying for 10 days effectively lowers the moisture content to a safe level for storage (8.85%). However, grain moisture content in all treatments ranges from 8 to 9 percent at the end of storage, the optimum water content for storage. Chauhan, Seth, Vyas, Kumar, & Navneet, (2017) reported that it takes 8 days to dry with sun-drying method to achieve optimum maize water content for storage (12%).

Total Seed Damage

The results showed that the loss and damage during storage was determined by the treatment of different drying times. Drying for 10 days, which resulted in 12.96% of seed moisture content, caused the lowest damage and loss (6.5%) compared to other treatments (Fig. 5). On the other hand, storage without drying caused severe damage, it reached 60% after 3 months of storage.

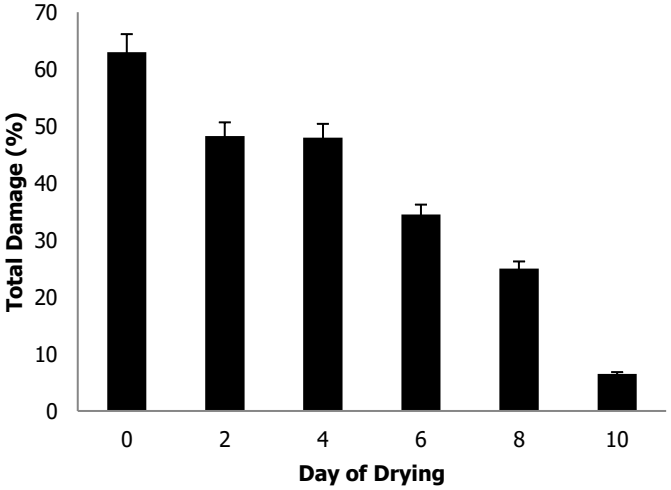

Figure 5. Total damage and losses of maize treated with different drying times, and stored for a 3-month storage

Biological and physiological factors are the causes of damage to the maize kernels in storage. Living organism such as fungi and insects, and thermal heat produced by respiration of the grain itself will enhance water vapor, which in turn will lead to further deterioration of the grain. As a general expression, the higher the moisture content, the more susceptible the maize grain to molds and insects (Suleiman & Rosentrater, 2015); Freer, Siebenmorgen, Couvillion, & Loewer, 1990; Wimberly, 1983). Hence, setting initial moisture content at optimum level (12 - 14%) before storage was essential to reduce damage and maintain quality during storage.

The results of correlation analysis showed that there was a positive correlation between initial water content and the total damage of grain during storage (Fig. 6). It means that the increase of initial water content will increase the damage of maize during storage. As a coefficient of water content (X) increase by one unit 100%), the damage or losses (Y) will increase by 2.17 units (217%).

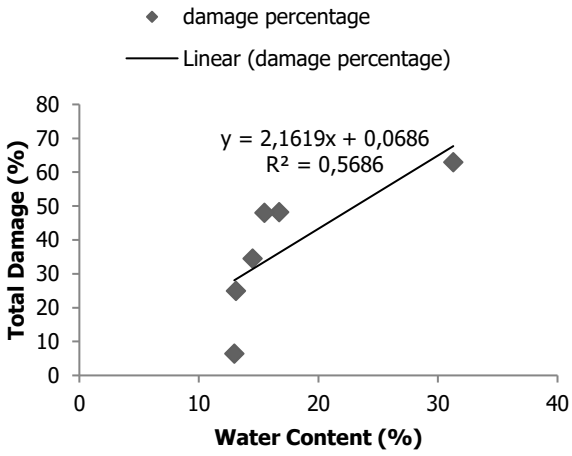

Figure 6. Correlation between initial water content and total damage of maize during storage

Identified Pathogen in Storage

The species of fungi identified during storage were *Aspergillus flavus, A. niger, A. fumigatus, Fusarium* spp*., Penicillium* spp*., Rhizophus* spp*.,* and *Mucor* spp*.* (Table 1). The fungi were found in all treatments except the 10-day drying treatment. Most of them are found as pre harvest *fungus* indicating that there has been an infection in the field. *A. flavus* is known as a very destructive fungus and it produces aflatoxin. Physical properties such as water content, temperature, and humidity influence the production of aflatoxin during storage. *A. flavus* and *A. parasiticus* thrive at the moisture level of 13 to 18% (Hettlarachchi *et al.*, 2001).

Table 1. The species of fungi identified during storage

Name of species	Found in sample
Aspergillus flavus	All samples accept A10
Aspergillus niger	All samples accept A10
Aspergillus fumigatus	All samples accept A10
Fusarium spp*.*	All samples accept A10
Penicillium spp.	A0, A2, A4, A6
Rhizophus spp*.*	A0, A2, A4, A6
Mucor spp*.*	A0

CONCLUSION

In conclusion, drying maize for 10 days before storage produces optimal initial moisture content (12.96 %) for storage that reduces damage and losses during storage. Storage with initial moisture content of 12.96 percent caused the lowest damage of 6.5% for 3 months of storage. The 10-day drying treatment prevented the infection of some fungi that destroyed the seeds during storage. There was a positive correlation between initial water content and the total damage of grain during

storage. It means that the increase of initial water content will increase the damage of maize during storage. Storage fungi such as *Aspergillus flavus, A. niger, A. fumigatus, Fusarium* spp*., Penicillium* spp*., Rhizophus* spp*., and Mucor* spp*.* are found in maize dried for less than 10 days with initial moisture content greater than 13%. This proves that drying for 10 days produces an optimum initial moisture content and suppresses damage and loss during storage and prevents fungal infections that cause damage and mycotoxin production in maize.

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