Postharvest Contamination of Thai Corn with *Aspergillus flavus*

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ABSTRACT

About 4.5 tons of ear corn were collected from three farmers and divided into four groups: 1) stored on the farm as ear corn for eight weeks, 2) shelled by hand and kept for two weeks in gunnysacks without drying, 3) mechanically shelled and kept for two weeks in gunnysacks without drying, and 4) mechanically shelled and kept for eight weeks in gunnysacks after drying. The undried, mechanically shelled kernels were infected quickly by *Aspergillus flavus* if the initial moisture content was over 20%, but infection did not occur if moisture was less than 17%. Similarly, in the undried, hand-shelled kernels, infection proceeded rapidly if moisture content was over 23% or stopped if it was less than 20%. Kernels that were sun-dried immediately after mechanical shelling on a drying floor (moisture content less than or around 15%) were stored without significant *A. flavus* infection for more than eight weeks after sun-drying. Wet corn could be stored for more than two months without *A. flavus* infection as long as corn was stored as ear corn and not shelled. The infection by *A. flavus* clearly started in kernels that were damaged by shelling and not dried enough afterward.

Throughout Thailand, corn is contaminated with *Aspergillus flavus* fungi that produce the carcinogenic metabolites aflatoxins (Siriacha et al 1983; Anonymous 1985; Asanuma and Vayuparn 1985; Tsuruta et al 1985; Goto et al 1986; Saito et al 1986a,b). Infection of Thai corn by *A. flavus* is generally thought to begin in the farmer's storage house and to become serious during storage by a middleman, on a drying floor or in a storage house, but the process has not been reported in detail (Goto et al 1986, Siriacha et al 1983, Yamamoto 1987).

This study aimed to pinpoint when and where *A. flavus* invaded corn after harvest and to identify ways to reduce the level of toxin contamination.

MATERIALS AND METHODS

Maize

Twenty gunnysacks (about 1.4–1.5 tons) of ear corn (SUWAN-1 around 115 days after planting) were obtained from three farmers' fields in Koktoom subdistrict, Muang district, and Lopburi Province, Thailand. Ears were harvested by hand from September 29 to October 1, 1987. These three groups are referred to as samples F1, F2, and F3.

Sample Treatment

Sample F1. Ears were sun-dried after harvest for nine days on a perforated iron drying bed about 60-cm above the ground. During sun-drying, it rained several times, and ears were covered with a waterproof cloth sheet. After eliminating the damaged, germinated, or moldy ears by hand grading, ears were stored for 11 days in the farmer's storage house made of wood and bamboo, which was 80-cm above the ground.

After this, the ears of corn were divided into four groups: 1) ears remained in the farmer's storage house in gunnysacks for an additional eight weeks; 2) ears were shelled by hand, and kernels were stored in gunnysacks without drying for two weeks; 3) ears were shelled in a mechanical sheller, and the kernels were stored in gunnysacks without drying for two weeks; 4) ears were shelled in a mechanical sheller, and the kernels were sun-dried on a middleman's concrete drying floor, then stored in gunnysacks for eight weeks. Grain in groups 2, 3, and 4 was stored at a middleman's storage house.

Sample F2. Ears were at first graded, and those with no commercial value were discarded. The ears were sun-dried for eight days on a farmer's drying bed made of bamboo, about 50 cm above the ground. Then they were stored in gunnysacks for 11 days in a concrete-floored storeroom adjoining the farmer's home. Ears were then divided into four treatment groups as in F1.

Sample F3. After harvest, ears of corn were immediately piled up for 11 days in the farmer's wooden storage house, about 120 cm above the ground, without any sun-drying or grading. Ears were then divided into four groups as in F1.

Detection of *A. flavus* in Infected Grain

Shelled kernels and ear corn (more than 5 kg as kernels) were collected regularly during sun-drying and storage. Two hundred kernels from each collection were surface-sterilized by washing with 3% NaOCl for 1 min and rinsing five times with sterilized water. Kernels were then incubated on a potato dextrose agar (PDA, Difco) plate containing rose bengal (30 mg/L) and chloramphenicol (30 mg/L) for five days at room temperature. The numbers of kernels infected by *A. flavus* were recorded.

Detection of *A. flavus* from Unhusked Corn

From each farmer's field, 20 sound, unhusked ears were randomly collected at harvest. The husks were cleaned with a disinfectant, and then aseptically removed. Kernels from the middle of the ear were collected, and 20 g were suspended in 100 ml of sterilized water. This suspension was diluted, mixed with PDA, incubated at room temperature (28–30°C) for three to five days, and the *A. flavus* colonies were counted.

Shelling

Between 350 and 400 ears (35–40 kg as grain) were shelled by hand. Mechanical shelling was done with a middleman's domestic sheller with a capacity of 7.5 tons/hr, and 550–850 kg of kernels was obtained. The hand-shelled kernels (35–40 kg) and 50–60 kg of the mechanically shelled kernels were kept in gunnysacks without any drying and stored in the middleman's storage rooms.

Sun-drying of Shelled Kernels

Mechanically shelled kernels from F1 (500 kg) and F2 (500 kg) were sun-dried on a middleman's (M1) concrete drying floor for 3.5 hr. Grain (800 kg) from F3 was sun-dried on another middleman's (M2) drying floor for 4 hr. During drying, grain was stirred every 30 min with wooden rakes in the traditional manner.

Dried grain was transferred to gunnysacks, and was stored in the middlemen's (M1 and M2) storage houses for eight weeks.

Moisture Content

A Steinlite moisture meter (model 90, Fred Stein Laboratories, Atchison, KS) was used to measure grain moisture content.

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RESULTS AND DISCUSSION

Moisture Content

Sample F1. Immediately after harvest, the moisture conent of kernels from corn ears was 28.6%, whereas after sun-drying for nine days as ear corn, it was 17.7% (Fig. 1). After 11 days of storage in the farmer's storehouse, the moisture was 16.9%. After mechanical shelling and sun-drying for 3.5 hr on the middlemen's drying floor, this was reduced to 13.7% mc (Fig. 2), which showed that sun-drying can be effective. After eight-week storage in gunnysacks, the moisture content of these sun-dried kernels was reduced to 12.8%.

Sample F2. Sun-drying of ear corn for eight days, reduced corn moisture by 0.54% per day from 26.6 to 22.3% (Fig. 1). This was rather slow compared with F1 due to unfavorable weather. Ears were then stored in gunnysacks at the farmer's storeroom for 11 days, during which moisture decreased.

After sun-drying for 3.5 hr, shelled grain had about 15% mc (Fig. 2). The moisture decreased by 1.9% after storage for eight more weeks.

Sample F3. Compared with F1 and F2, the initial moisture content was the lowest (24.8%) in F3 corn. The undried ears were piled in the farmer's storage house for 11 days (Fig. 1), during which moisture decreased by only 1.8%. After storage, ears were shelled and sun-dried. The shelled kernels lost moisture at the rate of 1.95%/hr for 4 hr on the middleman's drying floor (Fig. 2), which demonstrates the effectiveness of indigenous drying methods. Eight weeks after sun-drying, corn had 13.9% mc, which was close to the value in F1 and F2 (Fig. 2).

A. flavus Infection Level

Ear corn stored in farmers' storage houses. Generally the ear corn in each sample (F1–F3) had a low infection level of *A. flavus*; it was only 0.5–3.5% even after 67–76 days (Fig. 1).

The ear corn from F1 had poor quality due to drought, and infection by *A. flavus* did not increase during the first 11 days' storage or the next eight weeks' storage in the farmer's storehouse (Fig. 1).

The level of *A. flavus* infection in F2 corn ears was intermediate between F1 and F3. Moisture content was less than that of F3, and ears remained in good condition through 75 days in the farmer's storeroom (Fig. 1).

At harvest, the quality of F3 corn was the best when compared with the other two, and the infection level of *A. flavus* was the lowest of the three groups. Without sun-drying, ears were piled for 11 days and then kept in gunnysacks at higher moisture content for further eight weeks (Fig. 1), but growth of *A. flavus* was not observed.

Judging from the above results, Thai corn might remain free from heavy *A. flavus* infection even after long-term storage,

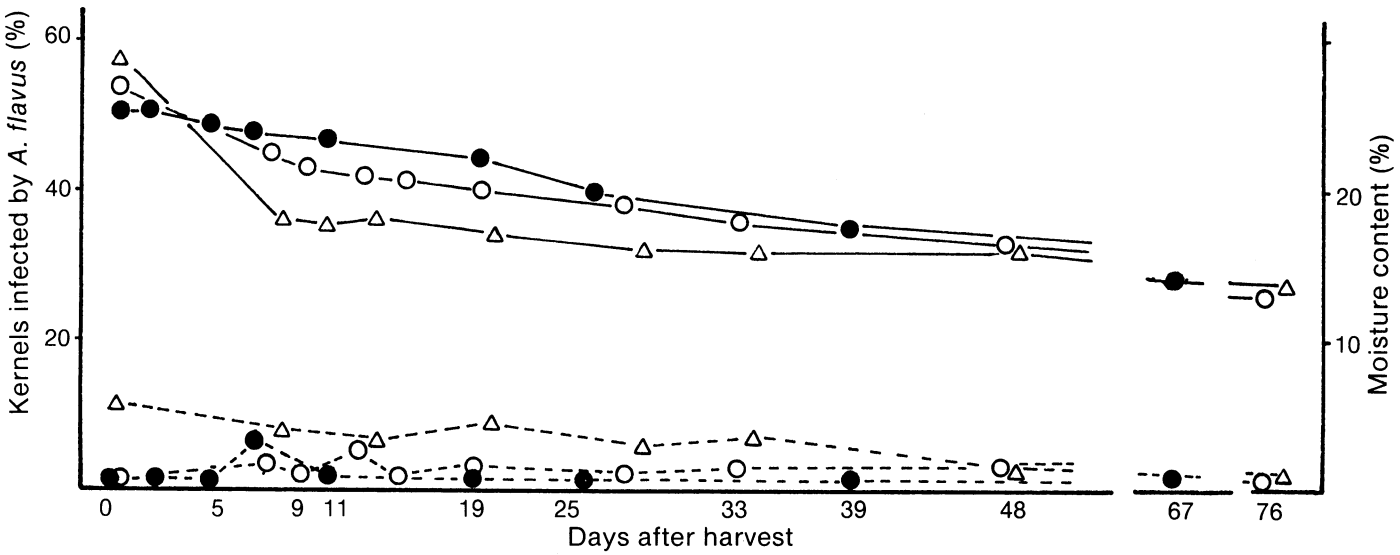

Fig. 1. Moisture content and infection of kernels by *Aspergillus flavus* in ear corn kept in the in farmer's storage house. Solid line indicates moisture content; dashed line indicates infected kernels; △ = F1, ○ = F2, and ● = F3.

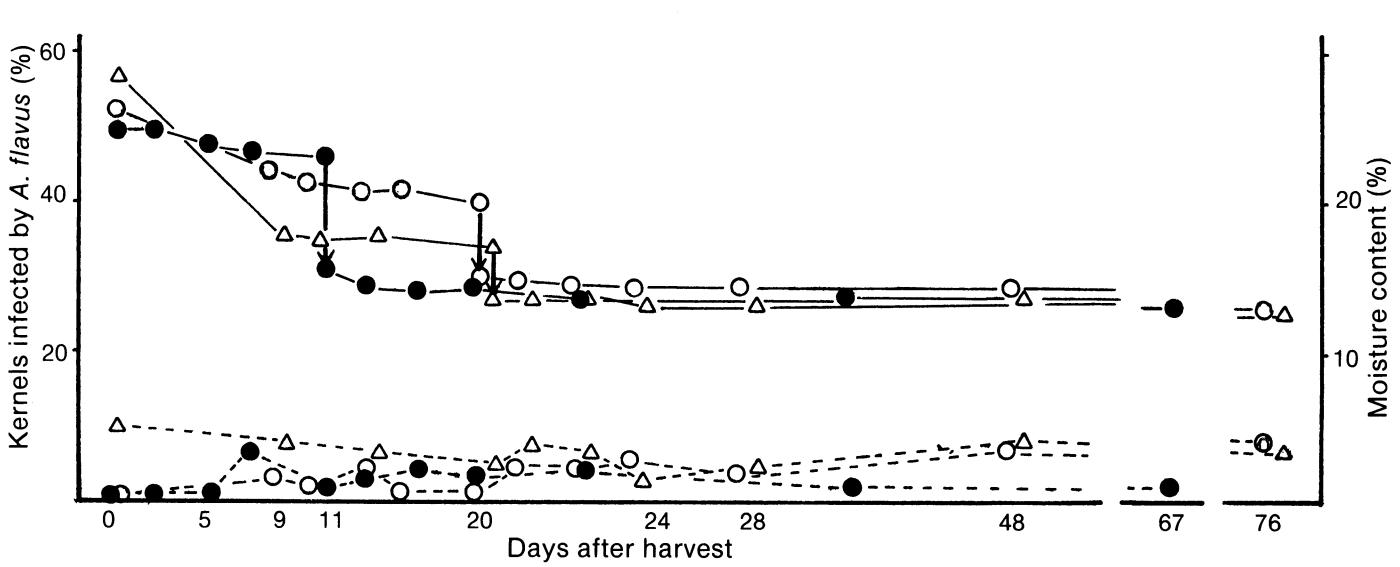

Fig. 2. Moisture content and infection of kernels by *Aspergillus flavus* in sun-dried grain. Solid line indicates moisture content; dashed line indicates infected kernels; △ = F1, ○ = F2, and ● = F3.

provided the corn is stored as ear corn with the proper moisture content.

Kernels shelled by hand. Hand-shelled kernels were kept in gunnysacks without any drying. *A. flavus* infection did not increase in F1 (initially 16.9% mc) and F2 (19.7% mc) for two weeks, but F3 hand-shelled kernels (23.0% mc) were heavily invaded by *A. flavus* after 8–10 days in gunnysacks (Fig. 3), even though F3 ear corn was initially less infected than F1 and F2 at harvest. The initial moisture content of hand-shelled F3 kernels was high, and it was almost always over 20% during storage in gunny sacks (Fig. 3). High moisture content might be the main cause of *A. flavus* infection. The moisture contents of kernels immediately after shelling and after 10-day storage, respectively, were 19.7 and 17.1% for F2 and 23.0 and 20.6% for F3. The critical moisture content for infection of hand-shelled kernels by *A. flavus* seemed to be around 20%. Below 20% as initial moisture, hand-shelled kernels were not infected by *A. flavus* (Fig. 3).

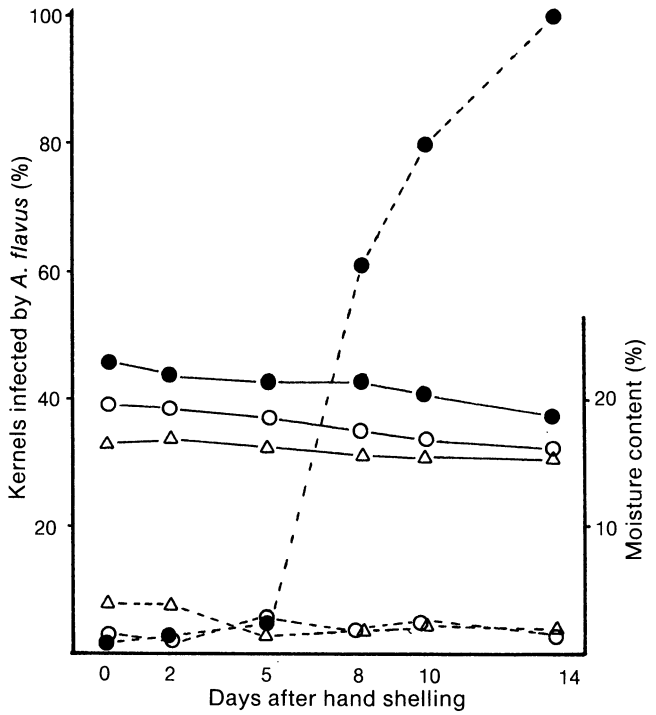

Fig. 3. Moisture content and infection of kernels by *Aspergillus flavus* in undried grain after hand-shelling. Solid line indicates moisture content; dashed line indicates infected kernels; △ = F1, ○ = F2, and ● = F3.

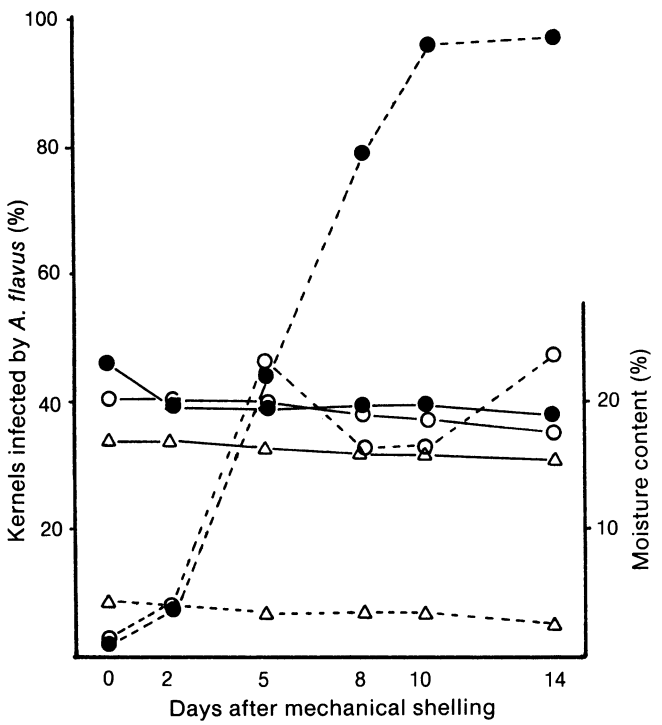

Fig. 4. Moisture content and infection of kernels by *Aspergillus flavus* in undried grain after mechanical shelling. Solid line indicates moisture content; dashed line indicates infected kernels; △ = F1, ○ = F2, and ● = F3.

The initial grading process, which eliminated the infected corn in F1 and F2, might also help to control the development of *A. flavus*.

Kernels shelled by machine. F1 corn was already infected with *A. flavus* to some extent in the field, and its quality was poorest of the three groups. However, the kernels that were shelled mechanically and stored for two weeks without drying had no additional growth of *A. flavus* (Fig. 4). Lopez and Christensen (1967) reported that *A. flavus* cannot invade corn kernels if moisture content is less than 17.0–17.5%, and moisture content of F1 kernels was below 17%. In sample F2, the infection by *A. flavus* of undried mechanically shelled kernels increased slowly (Fig. 4). The moisture content of F2 during storage (18–20%) was apparently high enough to allow some growth of *A. flavus*. Moisture content fell below 20% between five and eight days after shelling.

The hand-shelled F2 kernels had no increase in *A. flavus* infection (Fig. 3), whereas mechanically shelled F2 kernels had a slight increase (Fig. 4). Kernel damage caused by machine shelling is probably responsible for this difference. A machine that causes less grain damage should be developed, so that undried, shelled grain with around 19–20% mc can be stored for 10–14 days without heavy infection by *A. flavus* (Fig. 3).

Shelled kernels from F3 had high moisture content (23%) and were rapidly invaded by *A. flavus*. Both hand-shelled kernels and machine-shelled kernels were invaded, but infection was slower in hand-shelled kernels (Fig. 3). The growth of *A. flavus* usually spread from the tip cap of the kernel; the tip cap might be most heavily damaged by the shelling process.

In Thailand, quite often kernels cannot be sun-dried immediately after shelling during the main harvest season due to heavy rain. Furthermore, some farmers cannot afford a storage house, and they want to sell their high-moisture corn right after harvest to get money immediately. Local brokers and middlemen usually collect corn from farmers and shell it. Undried, shelled kernels are often piled up or packed in gunnysacks and kept in storage for several days until trucks come to collect them. It takes one to three days or more to move wet kernels from the field to the silo companies' drying facilities in the big cities. During that time, the infection of kernels by *A. flavus* spreads quickly.

Kernels that were sun-dried on a middleman's drying floor. There was no substantial increase in *A. flavus* infection of sun-dried kernels in F1, F2, and F3 during eight-week storage (Fig. 2). It is now clear that Thai corn, brought to less than 15% mc by sun-drying, is not subject to serious *A. flavus* contamination and, therefore, free of aflatoxin contamination even after long-term storage. Sun-drying might be simple, rapid, and effective if days are sunny, although some sun-dried corn is reported to be rather highly contaminated with aflatoxins (Siriacha et al 1983, Anonymous 1985, Goto et al 1986, Yamamoto 1987). Thai corn is harvested in the rainy season and rain may delay sun-drying and rewet corn kernels.

Unhusked ear corn. No *A. flavus* was isolated from any sound unhusked ear in F1, F2, or F3.

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