# U.S. stored-wheat pest management practices: producers, elevator operators, and mills

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*Abstract*

The U.S. wheat storage system is characterised by wide variation in types of storage facilities, management practices, and environmental conditions. Results from a recent survey highlight the differences in storage facilities, grain moisture conditions, and pest management practices throughout the U.S. wheat storage system. Stored grain management practices also vary among the levels of the marketing system, i.e. producers, commercial elevators, and flour millers. Surveys of Oklahoma producers and commercial elevator managers conducted over a 5-year period indicated important differences in the use of fumigation and other integrated pest management (IPM) practices. Producers and commercial managers also differed in their perception of discounts for infested grain. However, both producers and commercial managers appeared to be adopting improved IPM practices. Results from a nationwide survey of flour millers indicated that the marketing system is not communicating the miller's near zero tolerance for insects and pesticide residues to producers and commercial elevator managers.

## Introduction

Over 65 million t of wheat are harvested each year in the U.S. In 1990, the farm value of wheat production was US$7.3 billion, about 8% of the total value of U.S. agricultural production (National Agricultural Statistics Survey 1991a and b). There are eight classes of U.S. wheat: hard red winter, soft red winter, hard red spring, durum, hard white, soft white, unclassed, and mixed. During the 1981–1991 period, 46% of all U.S. wheat was hard red winter wheat, 21% was soft red winter wheat, hard red spring made up about 18%, white wheat was nearly 12%, and durum wheat accounted for about 5% of U.S. wheat production. Five states: Kansas, Oklahoma, Texas, Colorado, and Nebraska produced 78% of the U.S. hard red winter wheat (Adam and Anderson 1992).

The potential for losses from stored-grain insects and moulds are determined by storage time, management practices, grain temperature, and moisture. The stored-wheat environment varies dramatically across the U.S. The average harvest moisture content varies from a low of nearly 8% to a high of 15% across U.S. wheat production regions. The average temperature of wheat at harvest varies from 20°C to 35°C (Storey et al. 1979; Hagstrum and Heid 1988). Wheat harvest begins May 15 in Texas and ends in late August in North Dakota.

When evaluating the risk of storing grain, U.S. wheat producing stages can be separated into three regions. The low-risk (low temperature and low moisture) region includes Idaho, Montana, North Dakota, South Dakota, and Wyoming. The moderate-risk (moderate temperature, high moisture) region includes Colorado, Indiana, Minnesota, and Nebraska. The high-risk (high temperature, high moisture) region includes Kansas, Oklahoma, and Texas.

On-farm and commercial elevator storage systems vary significantly across the U.S. The south is characterised by limited on-farm storage (18%). Due to the high risk of insect and mould losses, most producers in these areas prefer to store their wheat in commercial elevators. On the other hand, in the low-risk areas the majority of wheat is stored on-farm. Commercial storage structures also vary significantly across the U.S. Grain is stored in round steel bins, concrete silos, and flat steel structures. The type of storage facilities in place are affected by the storage environment and when the facilities were constructed. Most concrete facilities were constructed in the 1950s and 1960s. Many of the flat and round steel structures were constructed in the 1970s and 1980s in response to government subsidised storage programs.

The storage system is important when considering pest management practices. Grain stored in round steel bins is difficult or impossible to turn, while concrete structures facilitate turning and blending. Fumigation is also affected by the type of structure. Most managers fumigate wheat in concrete facilities by using automatic pellet dispensers while turning the grain. This provides near perfect distribution and limits worker exposure. Fumigating round steel and flat steel structures is accomplished by probing the pellets/tablets into the grain mass and then covering the surface to minimise gas loss. This method is more labour intensive and increases worker exposure. Flat structures are the most time-consuming and have the greatest chance of failure due to the large surface to volume ratio and difficulty in adequately sealing the structures.

Flat and round steel bins are usually less than 15 m tall and are designed with aeration to control grain temperatures. Concrete facilities are often over 30 m tall and seldom have aeration capabilities. This is due to the time of construction and the reduced aeration efficiency in taller structures.

Insect, mould, and heating damage occurs in all segments of the grain storage system. While the management practices at each level depend upon the condition of the grain received, the sampling and grading procedures at the next level, and the economic incentives translated through the pricing and discount system, the interactions within this system are not well understood. A better understanding of the management practices and economic incentives at each level of the system is needed before integrated pest management strategies can be fully implemented and pesticide use can be reduced.

## Survey Results

### Producers versus commercial elevator managers

A study conducted by a multi-state stored-grain taskforce in 1986–87 compared the stored-grain management practices of

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producers and commercial elevator managers (Cuperus et al. 1990). Follow-up surveys of both producers and commercial managers were conducted in 1991 (Cuperus et al. unpublished research). These studies provide evidence of the differences in stored-grain management practices at the producer and commercial elevator level and the adoption of new management techniques.

Both producers and commercial managers identified insects and moisture as primary storage problems. However, the commercial managers demonstrated a greater awareness of the stored-grain management system by also including temperature and moulds as primary storage problems. Producers were also less likely than elevator managers to correctly identify the major insect pests. University tests of grain samples taken over 1980–1986 indicated that the lesser grain borer, *Rhyzopertha dominica* (F.), as the most serious pest. In the initial surveys the majority (69%) of the commercial managers and a minority of the producers (one producer) included the lesser grain borer in their list of the most important four insect pests. By 1991, 11% the producers and 70% of the elevator managers now ranked the lesser grain borer as a major pest.

Scouting stored grain and sampling incoming grain are also essential stored-grain management practices (Table 1). Commercial managers scouted more frequently than did the producers. In the initial surveys, 38% of the commercial managers scouted more frequently than once a month, as opposed to 5% of the producers. Ten per cent of the producers and 1% of the commercial managers never scouted their stored grain. Twenty per cent of the commercial managers did not sample incoming grain. Of the managers who sampled, 57% took one sample and 24% took two samples. The average number of samples taken among the managers who did sample was 1.6. By 1991, commercial managers had increased the frequency of their scouting, while the producers' practices were unchanged.

**Table 1.** Scouting intervals for wheat storage for on-farm and commercial storage in Oklahoma[a] (per cent)

| Interval | On-farm | | Commercial | |
|---|---|---|---|---|
| | 1986 | 1991 | 1987 | 1991 |
| Weekly | 5 | – | 17 | 29 |
| 2–3 weeks | – | 2 | 21 | 15 |
| Monthly | 54 | 51 | 34 | 32 |
| 2–3 months | 24 | 27 | 25 | 15 |
| 4–6 months | 4 | 5 | 2 | 1 |
| When grain is sold | 2 | 1 | 1 | 3 |
| Unchecked | 6 | 2 | 1 | 1 |
| Other | 4 | 9 | – | 3 |

[a]Data from surveys of 89 producers, 112 commercial managers, 95 producers and 160 commercial managers in 1986 1987, and 1991, respectively.

Table 2 provides a summary of the storage management practices of the producers and commercial elevator managers. Aeration is an important grain management and integrated pest management (IPM) tool. By reducing the temperature, the risk of moisture migration, insects, and moulds is reduced (Epperly et al. 1987). Producers were more likely to have aeration systems available. This was largely due to the type of grain storage structure used. All of the producers indicated that they stored grain in steel bins. Most steel grain bins, both on-farm and commercial, were equipped with aeration. However, commercial managers aerated a greater proportion of their grain. As the commercial storage environment generated excess storage capacity beginning in the late 1980s, commercial managers were able to concentrate their grain in bins with aeration. In 1991 the commercial managers aerated a significantly higher proportion of their grain with roughly the same amount of aeration equipment.

**Table 2.** Management practices in on-farm and commercial wheat storage[a] (per cent).

| | On-farm | | Commercial | |
|---|---|---|---|---|
| | 1986 | 1991 | 1987 | 1991 |
| Empty bin sanitation | 92 | 81 | 62 | 95 |
| Empty bin treatments | 85 | 84 | 88 | 90 |
| Grain protectants | 62 | 82 | 35 | 41 |
| Grain cleaner | 13 | 2 | 30 | 44 |
| Grain spreader | 17 | 13 | 3 | 26 |
| Fumigate immediately after binning | 18 | 18 | 15 | 18 |
| Turn grain | 16 | 15 | 88 | na |
| Routine fumigations | 34 | 38 | 84 | 66 |
| Bins equipped with aeration | 74 | 30 (concrete)<br>92 (steel) | 69 | 32 (concrete)<br>93 (steel) |
| Percentage of grain aerated | na | 25 (concrete)<br>63 (steel) | 43 | 69 (concrete)<br>92 (steel) |
| Rewarmed grain in spring | 13 | 4 | 20 | 9 |

[a]Data from surveys of 89 producers, 112 commercial managers, 95 producers and 160 commercial managers in 1986 1987 and 1991, respectively.

In 1986–87, 13% of the producers and 20% of the commercial elevators rewarmed grain in the spring. This practice is not in accordance with Oklahoma State University recommendations to leave grain temperatures low going into summer to reduce risk from insects and moulds. By 1991 only 9% of the commercial managers and 4% of the producers continued to rewarm grain.

Both the producers and the commercial managers applied integrated pest management practices. The use of empty bin sanitation, residual bin spray, dichlorvos resin strips, and top dressing were similar among both groups. The commercial managers were more likely than the producers to clean grain but less likely to use grain protectants. These differences probably resulted from structural and equipment differences. A commercial manager is more likely to have a cleaner available than is a producer. Since more of the commercially stored grain is in concrete facilities and is routinely turned, the use of grain protectants is less appropriate.

Commercial managers were more likely to use routine fumigations than were producers. In the initial surveys, 84% of the elevator managers and 34% of the producers routinely fumigated. These results are consistent with the risk environment and market incentives facing these managers. Insect infestations pose a greater risk to the commercial manager due to the higher storage volume. In addition, elevator managers face much more stringent sampling and discount policies when they sell wheat at terminal markets or flour mills than do producers delivering to country elevators. Since producers face a lower probability that infested grain will be detected, and less severe discounts, they have less incentive for routine fumigations. By 1991, the use of fumigation by commercial

managers had decreased reflecting the effectiveness of temperature management in reducing insect populations.

The producers' perceptions of discounts for infested grain differed from the stated practices of the commercial elevator managers (Table 3). Producers were less likely than commercial managers to indicate that the elevator policy was to refuse infested grain. Additionally, only 10–15% of the producers indicated that they were charged for the fumigation of infested grain, a stated practice by the majority of the elevator managers. The producers were consistently less likely than commercial managers to indicate that the elevator discounted infested grain. It is clear from the follow-up surveys that quality standards are increasing. By 1991, more producers and commercial managers indicated that infested grain was refused or that a discount was applied.

**Table 3.** Elevator action when infested grain is delivered for sale[a] (per cent)

| Action taken | Producers | | Commercial manager | |
|---|---|---|---|---|
| | 1986 | 1991 | 1987 | 1991 |
| Grain refused | 12 | 16 | 18 | 32 |
| Received and producer charged for fumigation | 11 | 14 | 59 | 52 |
| Discount applied | 9 | 22 | 20 | 62 |
| No discount | 6 | 8 | 3 | 14 |
| Never happened | 44 | – | – | – |
| Other | 18 | 3 | – | – |

[a]Data from surveys of 89 producers, 112 commercial managers, 95 producers and 160 commercial managers in 1986 1987 and 1991, respectively.

The commercial elevator surveys also indicated that elevators are adopting more stringent grading practices (Table 4). By 1991, the managers indicated that they were checking a greater variety of grading factors in their incoming wheat. A greater proportion of elevators had also adopted improved grading technologies such as power grain probes and mechanical grading equipment.

**Table 4.** Sampling procedures in commercial elevators, 1987 and 1991[a] (per cent)

| Procedure | 1987 | 1991 |
|---|---|---|
| Sample incoming grain | 98 | 99 |
| Samples per load (number) | 1.63 | 1.64 |
| Checked test weight | 60 | 75 |
| Checked moisture | 94 | 88 |
| Checked for shrunken and broken kernels | 38 | 71 |
| Checked for foreign material | 59 | 88 |
| Checked for insects | 76 | 99 |
| Checked for odour | 76 | 96 |
| Checked for sprout damage | 76 | 92 |
| Checked for mould | 71 | 91 |
| Checked for heat damage | 61 | 92 |
| Mechanical dockage machine | 33 | 62 |
| Power probe | 20 | 19 |

[a]Data from surveys of 112 commercial managers in 1987 and 160 commercial managers in 1991.

## Elevator management practices by region

A recent national survey of elevator managers (Kenkel et al. 1993) demonstrates that stored-grain management practices and pesticide use vary across the U.S. and are related to the risk level. Responses were received from 1020 managers in a 12 state area ranging from Texas to North Dakota.

The type and size of elevator facilities varies throughout the U.S. wheat storage system (Table 5). The southern region tends to have more concrete structures while the northern region has a greater proportion of round and flat steel storage. The southern (high-risk region) also tends to receive grain at higher moisture content and has equipped more of its storage facilities with aeration equipment (Table 6). Nationwide, most commercial managers ranked insects as their primary storage problem followed by moisture, temperature, and moulds. States in the low-risk region for insect and moulds such as Nebraska, South Dakota, and Indiana ranked moisture as a greater problem than insects or moulds.

**Table 5.** Presence of aeration in various commercial storage facilities throughout the United States[a] (per cent)

| State | Grain moisture content | Storage type | | |
|---|---|---|---|---|
| | | Round steel | Concrete | Flat steel |
| | | Mean | Mean | Mean |
| Colorado | 12.22 | 86.2 | 50.8 | 76.7 |
| Idaho | 9.92 | 52.7 | 8.9 | 38.9 |
| Indiana | 13.4 | 94.6 | 87.4 | 69.0 |
| Kansas | 11.97 | 88.8 | 61.6 | 78.4 |
| Montana | 11.02 | 25.0 | 0 | 0 |
| N. Dakota | 11.98 | 66.6 | 15.7 | 40.1 |
| Nebraska | 11.72 | 95.2 | 71.1 | 92.4 |
| Oklahoma | 12.17 | 80.7 | 38.5 | 73.3 |
| S. Dakota | 11.55 | 71.1 | 14.6 | 52.1 |
| Texas | 12.79 | 92.8 | 66.5 | 86.5 |
| Wyoming | na | 61.2 | – | 38.8 |
| Nationwide | | 81.2 | 51.3 | 68.9 |

[a]From surveys of 1020 commercial elevator managers.

While there was some variability between regions, all of the managers indicated frequent scouting intervals (Table 7). Most of the mangers scouted more frequently than once/month. Elevator managers use a wide variety of other integrated pest management practices such as sanitation, pre-bin treatments, grain protectants, and aeration. Essentially 100% of the managers surveyed used sanitation practices. Pre-bin products were used more often in steel facilities than in concrete. The use of empty bin treatments also varied with the risk environment. Approximately 86% of the managers in Texas and Oklahoma (in the high-risk region) used empty bin treatments as opposed to 67% in Montana (in the low-risk region).

Even greater regional variation was demonstrated in the use of protectants. Nationwide approximately 46% of the managers applied grain protectants during binning. However, the use of protectants ranged from 29–30% in Oklahoma and Colorado to almost 72% in North Dakota. In the case of protectants both the insect risk level and environmental conditions probably affected the managers' decisions. In the southern U.S., while insect risk is high, protectants are not as effective due to temperature degradation.

The use of fumigation also varied directly with the risk environment. Elevators in the southern plains (the high-risk

region) fumigated a much greater percentage of their stored grain than did elevators in other regions. These elevators were also more likely to routinely fumigate grain upon receipt. The number of fumigations within a storage facility varied with no apparent relation to the risk environment.

### Flour mills

The quality standards of flour mills were indicated to be much more stringent than commercial elevators (Table 8). The miller's standards exceeded the Federal Grain Inspection Service's (FGIS) standards for #1 hard red winter wheat in almost every area. The millers indicated stringent standards for both the absence of insects and the absence of pesticide residues. The surveys from Oklahoma indicated that only 22% of the producers perceive that they will be charged a discount (above the cost of fumigation) for delivering infested grain to the elevator. A higher proportion of the elevator managers (62%) indicated that their stated practice included a penalty for infested grain. It is obvious that the marketing system is not communicating the millers' quality needs to commercial elevator managers and producers.

All of the millers surveyed had sanitation programs in place. The majority also had quality assurance divisions and an integrated pest management program in place. However, the millers also indicated high usages of fumigation and residual treatments to control insects in their milling and warehouse areas. Due to the value of the product (relative to grain) and their high quality standards, millers cannot afford to let insect populations to reach detectable levels. A minority of the millers indicated that they had experimented with new integrated pest management tools such as heat treatments or controlled atmosphere ($CO_2$) fumigation (Table 9).

## Conclusions

The U.S. stored-wheat system is complex and encompasses a variety of storage technologies and environmental conditions. Producers, commercial elevator managers, and flour millers all contribute to the quality of wheat products reaching the consumer. However, the scouting and sampling practices, quality standards, and management practices vary significantly between each level of the marketing system. Managers at each level of the system face different risk environments and economic incentives. It is clear that all of these managers

**Table 6.** Fumigation practices and residual insecticide use at commercial elevators in selected states, 1992[a]

| State | Percent using sanitation practices | Percent fumigated upon receipt[b] | Percent fumigated during storage | Number of fumigations | Percent using empty bin treatments | Percent applying protectants during binning |
|---|---|---|---|---|---|---|
| Colorado | 89.29 | 11.9 | 27.5 | 2.2 | 64.3 | 28.6 |
| Idaho | 96.97 | 35.5 | 30.4 | 1.9 | 87.9 | 60.6 |
| Indiana | 97.56 | 16.0 | 19.0 | 1.9 | 91.4 | 42.7 |
| Kansas | 94.57 | 59.7 | 43.7 | 3.1 | 80.0 | 40.7 |
| Montana | 100.00 | 10.2 | 23.5 | 4.7 | 66.7 | 58.3 |
| Nebraska | 83.30 | 16.7 | 22.4 | 3.6 | 78.9 | 40.8 |
| North Dakota | 97.10 | 8.1 | 14.0 | 2.6 | 77.5 | 71.7 |
| Oklahoma | 96.43 | 73.1 | 76.4 | 1.9 | 86.6 | 30.3 |
| South Dakota | 96.59 | 18.9 | 25.8 | 3.6 | 67.0 | 58.0 |
| Texas | 93.18 | 68.1 | 65.2 | 2.3 | 85.6 | 34.1 |
| Wyoming | 100.00 | 33.3 | 15.0 | 1.0 | 66.7 | 66.7 |
| Nationwide | 95.3 | 37.5 | 37.5 | 2.7 | 80.1 | 45.6 |

[a]Survey during the fall of 1992 as part of a research project funded by the USDA–Pesticide Impact Assessment Projects. 1020 responses.
[b]Indicates receiving farm-stored wheat.

**Table 7.** Discount policies of hard red wheat elevators[ab]

| State | Response (%) | | | | |
|---|---|---|---|---|---|
| | Refuse grain | Charge for fumigation | Discount grain | No discount | Cents/bushel |
| Colorado | 28.6 | 42.8 | 21.4 | 7.1 | 6.3 |
| Idaho | 24.2 | 63.6 | 18.1 | 3.0 | 11.8 |
| Indiana | 26.8 | 23.1 | 42.7 | 2.4 | 7.7 |
| Kansas | 27.6 | 46.1 | 24.4 | 3.6 | 7.9 |
| Montana | 47.2 | 47.2 | 18.2 | 2.1 | 9.9 |
| Nebraska | 24.5 | 42.2 | 31.9 | 4.8 | 6.3 |
| North Dakota | 24.8 | 41.1 | 33.3 | 3.3 | 9.8 |
| Oklahoma | 21.4 | 40.2 | 33.0 | 8.9 | 6.8 |
| South Dakota | 27.2 | 46.6 | 45.4 | 6.8 | 8.5 |
| Texas | 28.0 | 26.5 | 14.4 | 3.0 | 8.7 |
| Nationwide | 38.5 | 26.8 | 30.0 | 4.7 | 8.1 |

[a]From surveys of 1020 commercial elevator managers.
[b]Numbers may be greater than 100% due to multiple answers.

have adopted and are adopting integrated pest management techniques. It is also clear that more research and educational programs are needed at each level. Future programs should focus on the interrelations of all levels of the stored-wheat system.

**Table 8.** FGIS standards for #1 HRW wheat versus millers' contract specifications.

| Quality factor | FGIS | Millers |
|---|---|---|
| Insect damaged kernels per 100 g | 32 | 7.2 |
| Foreign material per cent | 1.0 | 1.5 |
| Live insects (100 g)[a] | 2.0 | 0.2 |
| Pesticide residues (ppm) | 8.0 | 0.0 |

[a]The presence of two or more live insects injurious to stored grain or one live weevil will cause the wheat to be graded 'infested'. The numerical grade is not affected. n = 32.

**Table 9.** Integrated pest management systems presently used in mills.

| System | Percent used |
|---|---|
| Fumigation—milling area | 81.7 |
| Residual insecticide—milling area | 68.0 |
| Fumigation—warehouse area | 80.0 |
| Residual insecticide—warehouse area | 57.0 |
| Pheromone traps | 0.0 |
| Heat treatments | 4.0 |
| Carbon dioxide | 4.0 |
| Quality assurance division | 88.0 |
| Regular safety meetings | 88.0 |
| Emergency action plan | 92.0 |
| Planned integrated pest management schedule | 72.0 |

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