Different mills, different pests

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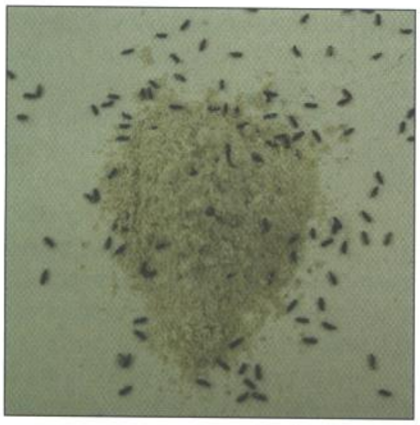
The interiors of feed mills attract insect pests because of conducive environmental conditions. In winter, feed mills offer warm temperatures, food sources—particularly raw and processed cereals—and moisture. These stored-product insects represent multiple risks to feed safety and quality. Management of insect pests is an essential prerequisite program for effective implementation of Hazard Analysis and Critical Control Points (HACCP) programs in feed mills. Identification of the types and numbers of pests present in a facility is the first step toward developing a pest management program.

A survey of stored-product insects associated with feed mills was conducted as part of a larger project designed to develop and implement a voluntary HACCP program in feed mills. Previously, only a few scientific studies had focused on stored-insects associated with feed mills in the USA, with the first published in 1956 and the most recent from 1983. Moreover, each of these surveys was limited to a single state and limited in the amount of quantitative information. Meanwhile, the emphasis on feed mill sanitation to enhance feed and food safety has continued to grow, so understanding the diversity of insect species in the mill and their management is becoming critical.



One of the most common stored-product insect pests is the red flour beetle, which K-State researchers captured in the pitfall type of trap (right) baited with food-oil, while they captured Indianmeal moths in sticky traps baited with sex pheromone.

Improvements in commercially available traps now make it easy to sample and monitor stored-product insects in and around feed mills. Researchers caution that environmental (temperature, food availability, moisture, trap location, trap design) and biological factors (age, mating status, sex, mobility, feeding status of insects) could impact trap captures. Also, in feed mill environments, traps and lures are competing with attractive food odors. Despite these limitations, traps are valuable tools for monitoring stored-product insects.

During 2003, we surveyed stored-product insects associated with eight participating feed mills, spanning five states in the Midwest, by using commercial food-baited and pheromone-baited traps. Our objectives were to identify types and numbers of insect species found in mills and to conduct insect community analyses based on the trap capture data.

Eight participating feed mills

Eight participating feed mills—identified as Mills 1-8—located in five Midwestern states were surveyed for stored-product insects. The mills differed in size, number of floors, and type of feed produced (see table, "Eight Midwestern"). The predominant feeds produced were for pigs, poultry, cattle, horses and pets. Mills 1, 3, 4, 5, and 8 were concrete structures, whereas the other mills were constructed of steel. Casual observations revealed accumulation of feed debris on floors and equipment in all mills except Mill 6, which had a rigorous sanitation schedule.

Researchers visited participating mills two or four times from January to November to sample insects with the commercial traps. The number of mill visits and the number of traps used for each of the mills were based on available resources and logistical constraints associ-

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Eight Midwestern feed mills surveyed for stored-product insects.

Mill ID[a]	State	No. floors	Total area	No. visits	Sampling dates[b]	Number of pitfall or sticky traps/visit[c] Receiving	Mill interior	Loadout	Mill exterior
1	MO	4	2,218.4 m^2	4	Jan 8, Mar 17, Aug 18, Oct 13	2	100	2	6
2	IA	2	259.0 m^2	2	Mar 31, Jul 9	20	25	0	5
3	IA	4	1,657.8 m^2	4	Jan 28, Jun 12, Jul 9, Nov 17	2	100	2	6
4	IA	3	1,087.7 m^2	2	Apr 3, Jul 10	0	50	0	0
5	OK	4	1,421.8 m^2	2	Jan 7, Mar 17, Aug 19, Oct 13	2	100	2	6
6	OK	1	2,743.9 m^2	2	Mar 26, Jul 2	0	50	0	0
7	NE	1	1,752.0 m^2	2	Apr 2, Aug 21	0	50	0	0
8	KS	3	3,721.0 m^2	2	Mar 27, Jul 3	13	37	0	0

[a]Mill ID: Mill identification for eight feed mills: Mill 1 produces mash and pelleted feed for poultry animals; Mill 2 produces mash and pelleted feed for poultry animals; Mill 3 produces mash and pelleted feed for pigs and poultry animals; Mill 4 produces mash feed for poultry animals; Mill 5 produces mash and pelleted feed for poultry animals; Mill 6 produces dog biscuits for companion animals; Mill 7 produces liquid, mash and pelleted feed for cattle, pigs, poultry and horses; and Mill 8 produces mash and pelleted feed for pigs.

[b]The sampling duration for all mills was 7 days, starting on the date listed.

[c]The food-baited and pheromone-baited pitfall traps for beetles and sticky traps for *P. interpunctella* males were paired at each location inside and outside the mill.

ated with travel and time.

Adult beetles were monitored by using commercial pitfall (Dome) traps with food bait oil and three separate pheromone lures. Each trap was fitted with a lure for *Tribolium* species (including the red flour beetle), *Trogoderma* species (including the warehouse beetle) and *Lasioderma serricorne* (cigarette beetle). Males of the Indianmeal moth (*Plodia interpunctella*) were sampled by using sticky traps baited with the moth's commercially available sex pheromone (Pherocon II).

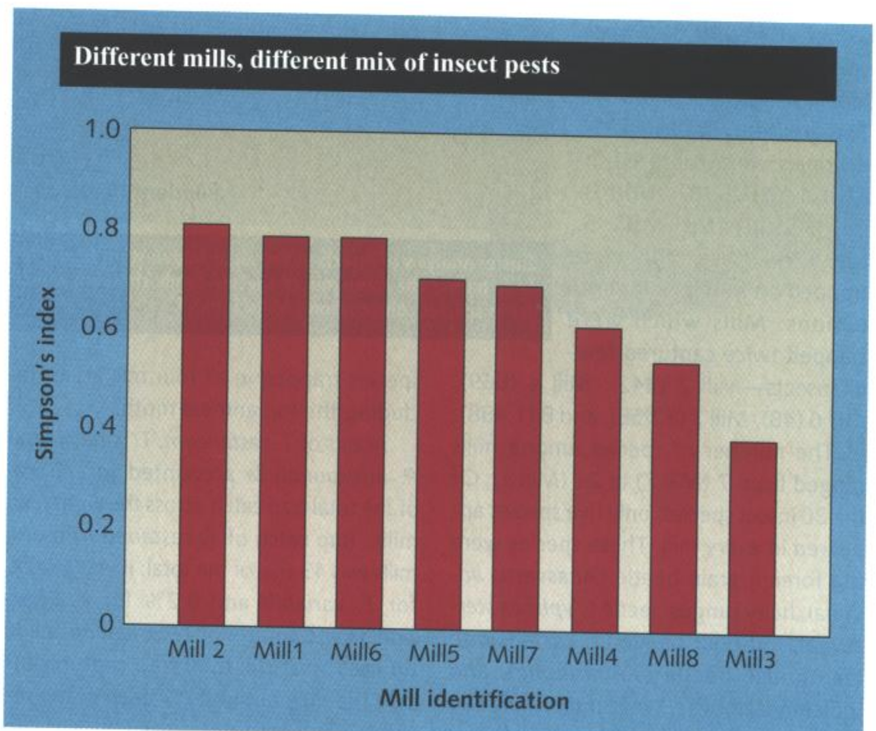
In Mills 1, 3, or 5, totals of 110 traps of each type were used for insect sampling; and in the remaining mills, 50 traps of each type were used. Traps were placed in the receiving and load-out areas of the mills and inside and outside the mills, with more than half of the traps placed inside the mills. Traps placed outside at each mill were placed around the perimeter of the building. Pitfall and sticky traps were paired and placed throughout the mill interior in a grid fashion. The pitfall traps were placed on the floor, whereas the sticky traps for the Indianmeal moth were hung at eye level (1.8 m). The trapping duration during each visit was 7 days. After 7 days, each trap was placed in a zipper-sealed plastic bag and brought to the laboratory for separation and counting of insects. Insects were identified to species where possible, and were expressed as number of insects/trap/7 d.

Temperature and relative humidity levels inside and outside mills were measured by placing one data logger (HOBO®from Onset Computer Corporation, Bourne, MA) inside and one outside each mill site.

One of the challenges of such a study is that the types and numbers of insects captured may be associated with the number of traps used and the number of mill visits. To determine this association, the total number of insects captured in the mill interior and the total number of species found were correlated with the number of traps used or the number of visits by using the CORR procedure (correlational algorithm procedure from SAS Institute).

Big diversity of stored-product insects

Midwestern states are subject to extremes of both ambient temperature and humidity, which have various effects on



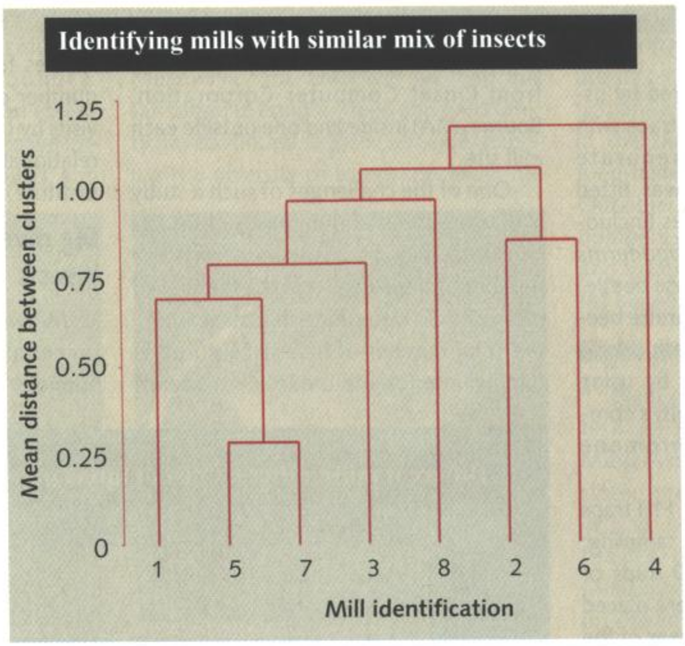
Even though a group of Midwestern feed mills may use the same major ingredients—corn and soybean meal—there can be big differences in the types of stored-product insects from one feed mill to the next, as shown by Simpson's Index of species diversity.

insect survival and reproduction. The feed mill environment reduces the extremes, providing in many cases a more equable environment for pests. During our survey, the mean ambient air temperature inside the mills ranged from 6.9°C to 35.1°C, while the outside air temperature ranged from -1.7°C to 31.5°C (<5.5% standard error for mean temperatures). The ambient relative humidity inside the mills ranged from 27% to 62.2%, and the outside humidity ranged from 37.9% to 73.3% (0.7-1.0% standard errors for mean relative humidity). Average temperatures by month across all eight mills ranged from a little over 11°C to nearly 22°C inside the plants. The average mill exterior temperature in January was 3.1°C and in November was 4.4°C. During the March through October visits, temperatures were 2°C to 10°C cooler than the mill interior temperatures.

Across all eight mills, the traps captured 44,397 individual insects of 30 insect species, representing 14 families in two insect orders. The greatest number of individuals were captured in Mill 1 (16,638), Mill 3 (13,352), and Mill 5 (8,352)—these mills were trapped on four different occasions. Mills which were trapped twice captured fewer insects—Mill 2 (342), Mill 4 (669), Mill 6 (48), Mill 7 (3,558), and 8 (1,438).

The number of species among mills ranged from 7 (Mill 7) to 21 (Mill 3). Of the 30 insect species, only five species appeared in every mill. These species were the foreign grain beetle (*Ahasverus advena*), hairy fungus beetle (*Typhaea stercorea*), red flour beetle (*T. castaneum*), warehouse beetle (*T. variabile*), and Indianmeal moth (*P. interpunctella*). Two species— *Cryptolestes* and *Anthicus* species—were captured in seven mills, while the granary beetle (*Sitophilus granarius*) was trapped in six of the eight mills. The remaining species identified were found in one to five mills. Correlation analysis showed that the types and number of insect species captured in traps were influenced positively and significantly ($P < 0.05$) by the number of traps used and the number of mill visits.

The types and numbers of insect species trapped differed among the four mill areas. In the receiving area of mills, 19 species were found. In the mill interior, 30 insect species were found. The load-out and mill exterior areas each had 15 insect species. There were 11 insect species trapped in all four mill areas, including the Indianmeal moth.



Cluster analysis of insects at the eight Midwestern feed mills confirms that none harbor the same mix of species, while showing which are most similar in species composition—Mills 5 and 7.

Adults of *T. castaneum*, *T. variabile* and *P. interpunctella* accounted for 70.9% of the total trap catch across the eight feed mills. Trap catch of *T. castaneum* among mills was 43.6% of the total; it was 18.6% for *T. variabile* and 9.2% for *P. interpunctella*. Captures of *T. castaneum* made up 49.1% of the total trap captures inside the mill, about 11% each in the receiving and load-out areas and 1.1% in the mill exterior. Most of the *T. variabile* (89.9%) were trapped outside the mill, followed by the load-out area (66.9%), receiving area (38.2%), and inside the mill (10.0%). Captures of *P. interpunctella* were fewest in the load-out area (2.8%) and outside the mill (2.2%), but captures in the receiving area and inside the mill were essentially similar (10% and 10.2%, respectively).

Large populations of select insects in certain mills

Some insect species were captured in great numbers in certain mills. For example, the small eyed flour beetle (*Palorus ratzeburgii*), the drugstore beetle (*Stegobium paniceum*), and the predaceous hister beetle (*Carinops pumilio*) were found in great frequency in Mill 3—*P. ratzeburgii* from this mill accounted for 97.7% of all the individuals of this species captured among all eight mills. More than 83% of each of the other species were captured in Mill 3. In another example, the slender seedcorn beetle (*Clivinia impressifrons*) from inside Mill 4 made up 93.7% of all this species captured among the mills. The saw-toothed grain beetle (*Oryzaephilus surinamensis*) was captured in large numbers in Mill 7—94.4% of the total for this species.

An analysis of the diversity of stored-product insect species in the eight feed mills found that species diversity was low for Mill 3, moderate for Mills 4 and 8, and high for the remaining mills (see figure, "Different mills"). The insect species trapped were most similar between Mills 5 and 7, although there was little similarity between mills in species composition (see figure, "Identifying mills").

The average number of insects captured inside the mills was significantly different ($P < 0.05$) among the sampling occasions or visits—except for Mill 2. Similarly, in Mills 1, 2, 3, 5 and 8, the mean number of insects captured in traps placed in the receiving, load-out, and mill exterior areas varied among the visits. In general, however, trap captures both in the mill interior and in receiving, load-out, and mill exterior areas were significantly greater ($P < 0.05$) during July and August. Trap captures, especially in August were greatest both inside and outside of Mill 1, compared with captures at the other mills. In Mill 1, twice as many insects were captured in traps placed in the receiving, load-out, and mill exterior areas, than in traps placed in the mill interior.

Increasing temperatures, increasing pest load

Insect activity was detected at all mills, as demonstrated by captures in traps in the mill interior and exterior during January to November visits. Insect activity increased with an increase in temperature. The increased captures in August suggest that pest management measures should be instituted during the winter months or before the onset of warm temperatures to discourage populations from reaching damaging numbers.

Three moth species were captured in sticky traps at the eight mills. Of the 27 insect species captured in pitfall traps, six species were not stored-product insects. Some of these insects feed on live or dead insects and are capable of attacking seeds of germinated, but not yet emerged, seedlings of several grains. One of these—*C. pumilio*—feeds on eggs and small larvae of house flies, and casual observations of house flies were made at the mills. The presence of house flies indicates unhygienic conditions within food stores, such as rotting materials or dead animals. The ability of *C. pumilio* to acquire and internally harbor pathogenic strains of bacteria such as *Salmonella enteritidis* makes the presence of this species a risk for feed safety. Other researchers have reported *C. pumilio* from other feed mills in the USA and abroad.

Midwestern feed mills typically use corn in their feed products, and the presence of *Sitophilus* species, especially the maize weevil (*S. zeamais*), is not surprising because these species are associated with whole grains, and immature stages of these species develop within grain kernels. However, the numbers of these species captured in pitfall traps were small (<0.8%) relative to those of other species. The corn that is received at the mills is processed within a month, thereby preventing these species from becoming well established in the mills. By contrast, species of Cr *Cryptolestes*, *Oryzaephilus* and *Tribolium* are associated with whole grain, broken kernels or grain dust, which are present in abundance in the feed mill. Other species, such as *A. advena* and *T. stercorea*, have been reported from stored grain, although they also are known to survive and reproduce on molds associated with cereal grains, which can be abundant in feed mills in the Midwest.

The abundance of *T. castaneum*—especially in the mill interior—is due to the high availability of feed dust, which this species prefers. However, it is important to realize that the pitfall traps had lures specifically for *Tribolium* species and these lures could also have contributed to increased capture of this species to the exclusion of other stored-product insects. Conversely, the small numbers of other stored-product beetles captured in pitfall traps could be due to the low absolute densities of these species in mills or their avoidance of the traps. These unknown factors are a good reason to survey for stored-product insects by sampling and sifting both static and moving grain mill

Mill insects as vectors for bacterial antibiotic resistance

The recent research at Kansas State University on stored-product insect pests in feed mills led to studies focused on the pathogenic bacteria carried into the mill by the insects. Some of these bacteria could pose a direct, feed-borne threat to animals and humans, but they also could pose a less obvious, but more sinister threat by transferring genes for resistance to certain antibiotics used in human medicine.

Studies dating from the late 1960s had discovered that insects in grain could be a reservoir for bacteria. In the early 1970s, researchers had found *Salmonella, Streptococcus* and other pathogenic species in insects in poultry houses. Until the K-State research, however, there were no studies addressing the association between stored-product insects in feed mills and Enterococci species. These gram-positive, catalase-negative, cocci-type bacteria are common in the environment and occur in animals' digestive tracts and feces as well as soil, contaminated water and food products from animals. The Enterococci species usually are not primary human pathogens, but are nosocomial—causing disease in hospital patients and staff and people with compromised immune systems.

At K-State, the researchers screened live adult beetles collected from six of the Midwestern mills involved in their work on insect pest control. Enterococci were isolated from seven out of nine insect species collected, with a particularly high occurrence in the red flour beetle. Then the workers screened the Enterococci organisms for sensitivity to eight antibiotics: Tetracycline, ampicillin, erythromycin, vancomycin, chloramphenicol, ciprofloxacin, streptomycin and neomycin. They found that *E. faecium* isolates displayed complete or intermediate resistance most frequently, especially to neomycin, tetracycline and erythromycin. Moreover, they found that many *E. faecium* isolates were intermediately resistant to vancomycin.

Previous research by others had found that such resistance to antibiotics indicated a potential health risk by means of "horizontal transfer" of antibiotic resistance genes to other bacteria, including more lethal human pathogens, such as *Staphylococcus aureus.* ■

stocks to determine whether populations are established in the mill and to assess the absolute density of various species.

The diversity of insect species present in mills and lack of a strong similarity among mills in species composition could be related to the geographic locations of the mills, type of feed produced, and degree of sanitation and pest management practiced. Nonetheless, Mill 6 had the best sanitation among all the mills, and this mill also had very few insect captures in traps.

The feed mill's environment inevitably attracts and supports stored-product insects. Also, there may be a fair amount of movement of insects from the mill interior to exterior and vice versa. Several investigators note that simple practices—such as closing doors, screening windows, using plastic sealant strips, or installing air curtains near doorways—help to keep insects outdoors. Besides increasing the risk of direct losses, stored-product insects represent vectors for the spread of pathogenic micro organisms in the feed mill. Moreover, the microbes traveling with the insects may be a reservoir for bacterial genes which can confer resistance to common antibiotics. This antibiotic resistance can be transmitted to other bacteria (see box).

Regular sanitation of mill floors and equipment, proper equipment maintenance, inspection of inbound raw ingredients, stock rotation and use of crack-crevice sprays in an integrated pest management program all help lower the risk and damage of insect infestation. Increasing pest-deterrent housekeeping and responsive tactics—such as fumigation or heat treatment—may be necessary in advance of summer months in order to prevent an unacceptable level of infestation.

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> The plant with the best sanitation among all the mills also had very few insect captures in traps.

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