Hot Technology for Killing Insects

Infrared energy shows promise as a grain disinfestation tool

Occasionally, I get inquiries about new technologies and products for managing insects in grain storage and food processing facilities. Many advances have been made recently in the development or evaluation of new and effective products and technologies for management of stored grain insects.

These new developments include spinosad, Storicide, Diacon II, carbonyl sulphide, ozone, and ECO_2FUME.

Several companies and researchers are re-examining old technologies as alternatives to conventional pesticides. These old technologies never met commercial success, because they were not cost-competitive with conventional pesticides, which were quick acting and effective against a broad range of insects.

There is renewed interest in exploring, or at least modifying, some of the old technologies in light of the restrictions or phaseout of existing pesticides. The impetus for this interest can be attributed to strict federal regulations, consumers' concerns regarding pesticides in their diet, and perceived adverse effects of pesticides on the environment.

I am in favor of re-examining old technologies, especially if they are effective against insects and cost about the same as conventional pesticides. In this article, I will review and share some of my experiences about an old technology that may have great potential for managing insects in stored grain.

The technology in question is the use of infrared energy for disinfesting grain. For readers who are unfamiliar with infrared energy, it is the electromagnetic energy that has a wavelength between 0.075 and 1,000 micrometers.

The wavelength of infrared energy is higher than that of visible light (380-750 nanometers) and less than that of microwaves (0.1-100 cm).

Past Tests With Infrared Energy

Like microwaves, grain and insects heat up by absorbing infrared energy or non-ionizing radiation.

Heat energy from infrared sources was tested by the U.S. Department of Agriculture (USDA) scientists to control grain insects in the early 1960s and '70s, although the first report in literature dates back to 1944.

Pest Management

Dr. Bhadriraju Subramanyam

Among the primary USDA scientists involved in evaluating infrared technology for grain disinfestation were R. L. Kirkpatrick, J. H. Brower, E. W. Tilton, and H. H. Vardell.

These scientists compared infrared with microwave radiation and found that infested grain exposed to infrared heated faster—and the insect control was better—than grain exposed to microwaves.

In their tests, the surface temperature of the infrared heaters was 1,699 degrees F, and these heaters produced a peak infrared emission at 2.5 micrometers.

Nearly 99.7% of rice weevils and 99.3% of lesser grain borers were killed by exposing soft red winter wheat to infrared heaters to obtain a grain temperature of 119.5 degrees F.

At this temperature, only 75% of immature rice weevils and 83% of immature lesser grain borers developing within kernels were killed, when grain was cooled soon after infrared exposure to 78.8 degrees F.

However, delaying cooling of grain exposed to infrared to 100 degrees F in 48 hours resulted in 99.8% and 93% mortality of immature rice weevils and lesser grain borers, respectively.

Generally, older life stages of the lesser grain borer and younger life stages of the rice weevil were highly susceptible to infrared radiation. Besides age, the susceptibility of insect species is also a function of how far the grain and insect samples are from the heaters, duration of exposure, heat intensity (pressure), and grain moisture.

For example, exposure for 5 seconds of 200 grams of rough rice of 14% moisture at a distance of six inches from the infrared radiation source increased the rice temperature to 107.8 degrees F. However, a 10- and 15-second expo- sure resulted in rice temperatures of 127.4 and 145.2 degrees F, respectively.

The ability of infrared radiation to kill immature lesser grain borers and rice weevils in rough rice was at commercial levels (greater than 95% dead), when the infested samples were 6 inches as opposed to 14 and 20 inches from the heater after 15 seconds of exposure.

At short exposures (less than 30 seconds) to infrared radiation, the moisture content dropped by about 0.5% or less. Similar results were observed in tests with wheat.

The reduction in immature-to-adult emergence of both rice weevils and lesser grain borers was greater, when infested grain was subjected to infrared radiation under vacuum (25 mm Hg), as opposed to those subjected to infrared radiation at normal atmospheric pressure.

New Infrared Heaters

I recently came across an advertisement in a 2003 issue of *Milling Journal* on a new method of generating infrared energy using flameless catalytic technology **(see www.catalyticdrying.com)**.

In this technology, infrared energy is generated when natural gas or propane is combined with oxygen in the presence of a heated catalyst (platinum). The resulting reaction releases infrared energy at wave-lengths of 3 to 7 micrometers.

The surface temperatures of the infrared heaters are 700 to 800 degrees F, significantly lower than the ones tested by the USDA scientists.

Scientists at the University of Arkansas have been evaluating a benchtop model of the flameless catalytic infrared energy for killing immature stages of rice weevils in small samples of rough rice.

The results are encouraging and show that exposures of 45 to 55 seconds to infrared energy, which resulted in grain temperatures of 140 or 158 degrees F, completely prevented emergence of adults from the infested kernels.

The main focus of the University of Arkansas scientists is to use this new technology for rice drying.

Insect Mortality

Mortality of adults of three insect species exposed to flameless catalytic infrared heaters, January 12, 2004.

Insect species	Amount of food product (lb)	Exposure time (sec)	Product temperature(°F)	No. dead/ total	% dead
Sawtoothed grain beetle	0.25	10	113	21/100	21.0
	0.25	15	135	96/100	96.0
	0.25	15	140	100/100	100.0
	0.25	30	149	100/100	100.0
	0.25	30	156	95/100	95.0
Rice weevil	1.00	60	142	216/220	98.2
	0.50	30	140	254/254	100.0
Red flour beetle	0.50	30	142	268/268	100.0

Note: The material was placed in one square foot stainless steel holder, and during the exposure period was shaken to simulate what would happen on a vibrating conveyor. Three to four temperature measurements of the product were taken immediately after exposure to infrared heaters, and the highest reading is presented in the table. Rolled oats were used for the sawtoothed bettle test and paddy rice for the rice weevils and red flour beetle tests.

Catalytic Infrared Energy Exposure

I took cultures of three stored grain insects to the company that makes the flameless catalytic infrared dryers and exposed these insects in products for specific time periods to determine mortality.

A pilot scale infrared heater was used to expose infested products. Briefly, the test involved exposing unsexed adults of mixed ages of the sawtoothed grain beetle in one-fourth of a pound of rolled oats for 10, 15, or 30 seconds.

Rice weevil adults were exposed in one-half- and 1-pound lots of paddy rice for 30 and 60 seconds, respectively.

Red flour beetle adults were placed in a half-pound of paddy rice and exposed for 30 seconds. Infested samples were placed in a 1-ft.-x-1-ft. stainless steel holder with a handle.

Unlike tests conducted by USDA scientists, infested grain was shaken manually for specified time periods, to ensure exposure of all sides of the kernels to infrared energy. In addition, this shaking simulates exposure of kernels to infrared energy on a vibrating stainless steel conveyor.

> I am in favor of re-examining old technologies, especially if they are effective against insects and cost about the same as conventional pesticides.

After the specified exposure time, temperature of the sample was taken using an infrared gun. The temperatures measured with the gun are approximate, and tend to provide a crude measure of temperatures attained by the infested samples.

A 10-second exposure of sawtoothed grain beetles resulted in a product temperature of 113 degrees F and produced only 21% mortality of adults (*see table, left*).

A 15- or 30-second exposure produced complete mortality of adults. All rice weevil adults were dead after 30 to 60 seconds of exposure, and all red flour beetle adults were killed after 30 seconds of exposure.

These preliminary findings are very encouraging, and additional replicated tests are planned to determine the effects of flameless catalytic infrared energy on various life stages of internal and external stored grain insects.

There were some conflicting reports in literature on the changes in the quality of flour from grains exposed to infrared energy, including effects on some rheological, and organoleptic properties.

Our ongoing tests, besides examining the adverse effects of infrared energy on insect pests, will also thoroughly evaluate the effects of this energy on the quality of exposed grain, primarily wheat, and quality of flour and flour products made from such grain.

Bhadiraju Subramanyam (Subi) is a professor in the Department of Grain Science and Industry at Kansas State University, Manhattan; 785-532-4092, bhs@wheat.ksu.edu.

Reprinted from the First Quarter 2004 Issue of Milling Journal.

Hot Technology for Killing Insects [part II]

Catalytic infrared heaters effective on insects developing in stored wheat

In part one of this column, which appeared in the first quarter 2004 *Milling Journal* (pp. 48-50), I described a new method for disinfesting grains using flameless catalytic infrared radiation. In this column, I present new data—not only for killing external stored-product insects, but for internal stored-product insects on stored wheat.

Pest Management

Dr. Bhadriraju Subramanyam

In the present tests, we used both a benchtop infrared source and a commercial infrared source.

Benchtop Model Tests

The benchtop model of the flameless catalytic heater has a circular heating surface of 613.4 cm^2 (27.94 cm diameter) that produces infrared energy in the 3 to 6 micrometer range using propane gas. Temperature across the heater surface, measured at 13 points using an infrared thermometer (Raytek® Ranger® MX4TM, Santa Cruz, CA), ranged from 356.3 to 474 degrees C. The propane gas pressure was 27.94 cm of water column (0.4 psi), and the total heat energy output of the unit was 1.47 kw/h (5,000 BTU/h).

Hard red winter wheat of 12% moisture was infested with 25 unsexed, 2-week-old adults of the red flour beetle taken from laboratory cultures reared at 28 degrees C and 65% relative humidity (RH). The three factors examined were: quantity of grain (113.5, 227, 340.5, and 454 grams), distance from the heater (12.7 and 25.4 cm), and exposure time (30, 45, and 60 seconds).

Each quantity of grain, distance from the heater, and exposure time combination was replicated three times. Grain temperature during exposure was measured continuously using the infrared thermometer connected to a top computer via a RS232 cable. The thermometer works in the 8 to 14 micrometer range and has a response time of 250 msec with an accuracy of ±1°C. An emissivity of 0.95, typical for organic materials, was used.

Calibration of the infrared thermometer with mercury thermometer indicated that the infrared thermometer readings were as accurate as that with a mercury thermometer. Temperatures were averaged every second over the exposure to obtain a single value for each replicate.

Table 1. Commercial Tests with Adults of Four Stored-Product Insects

Species	Temp Range (°C)	Total No. Adults	% Mortality
Red Flour Beetle	64-82	200	100
	57-71	1554	99.6
Rice Weevil	41-77	200	100
Merchant Grain Beetle	40-82	2002	100
Lesser Grain Borer	57-71	2034	98.9
	63-76	2707	100

Grain was exposed in a 27.94-cm-diameter stainless steel pan in a single layer. After exposure to infrared energy, the grain sample with insects was placed in 0.94-liter glass jar with mesh lid. After 24 hours, the grain was sieved to count the number of live and dead insects. Percentage of mortality was calculated from the number of dead insects out of the total exposed.

The grain temperature increased with an increase in exposure time, as expected, and was highest at the lowest quantity of grain. Also, low grain quantities heated faster, as expected, compared to higher grain quantities. Grain at 12.7 cm from the heater heated faster than grain 25.4 cm from the heater.

Insect mortality was a function of temperature, which was affected by the distance from the heater, grain quantity, and exposure time. A temperature of 80 degrees C was required to kill all red flour beetle adults. USDA scientists R.L. Kirkpatrick and E.W. Tilton in their 1972 paper observed 99.6% mortality of red flour beetle adults when soft red winter wheat was exposed for 20 to 40 seconds, resulting in a grain temperature of 65.5 degrees C. The output of the heater they used was 48,000 BTU/h as opposed to 5,000 BTU/h in our study.

Although grain quantity at 12.7 cm or 25.4 cm from the heater source had little effect on grain temperatures attained, it influenced mortality of red flour beetle adults because in small grain samples the insects perhaps were heated to a higher temperature than the grain.

Commercial tests

Commercial tests were conducted with a commercial heater, which was 6.1 m (20 feet) long and 61 cm (2 feet) wide. Eight infrared heaters were used in the study. The distance between the slanted heater surfaces and a vibrating steel conveyor surface was 4.4 cm (1.7 inches) at the lowest point and 8.9 cm (3.9 inches) at the highest point. All eight heaters produced 216,000 BTU/h.

The grain flow rate was 1,308 kg/h (2,800 lb/h). Natural gas was used to produce the infrared radiation, and the natural gas pressure was 0.13 psi. The grain was treated in a single layer and exposed for a total duration of 43 seconds. The amount of heat was regulated by increasing the gas pressure.

One end of the heater had a gate to dump grain and the other had a barrel to collect grain exposed to the heaters. We exposed adults of the red flour beetle, rice weevil, merchant grain beetles, and lesser grain borers from laboratory cultures using wheat.

All beetles were examined 24 hours after exposure and their mortality was assessed. The mortality of all the exposed species ranged from 98.9 to 100% (see Table 1). In another test, we infested wheat with lesser grain borers for three days and the adults were removed so that we could obtain stages of different age borers developing internally.

This wheat was exposed to the infrared radiation and after exposure was brought to the laboratory and incubated in a growth chamber at 28 degrees C (82.4°F) and 65% RH until the emergence of adults. Wheat infested similarly but unexposed to infrared radiation served as the control treatment.

Emergence of lesser grain borer adults in infrared-treated grain relative to unexposed grain was used to determine the degree of control (see Table 2). Reduction in adult lesser grain borer emergence was 98.8 % to 100% in infrared treatments.

These results document that short exposures to infrared radiation (60 seconds or less) can be used to control stored-product insects developing internally or externally in stored wheat.

Bhadriraju Subramanyam (Subi) is a professor in the Department of Grain Science and Industry at Kansas State University, Manhattan. He can be reached at 785-532-4092 or sbhadrir@ksu.edu.

Table 2. Emergence of Lesser Grain Borer Adults

Days Since Adult Infestation*	Emergence of Adults in Untreated Wheat (50 g)	Emergence of Adults in Infrared Exposed Wheat (50 g)	% Reduction Adult Emergence
18-22	17.2	0	100.0
13-17	84.1	1	98.8
7-11	60.3	0	100.0
2-6	42.1	0.1	99.8

*Wheat infested at different dates were pooled to obtain a range of infestation dates.