

# Effect of Humidity on Heat Treatment

During a heat treatment, temperature is biggest factor in determining survival rates

Heat treatment refers to heating mills or food processing facilities from 50 degrees C (122 degrees F) to 60 degrees C (140 degrees F) for 24 to 36 hours to control stored-product insects.

Heat treatment is a viable alternative to methyl bromide fumigation. However, the effect of humidity on the survival of insects during a heat treatment is unknown.

Therefore, unreplicated experiments were conducted at Kansas State University (KSU) to determine the survival of adult red flour beetles exposed to a range of humidity levels during an actual mill heat treatment.

#### Test Methods

All experiments were performed on the third floor (reduction floor) of the pilot flour mill, located in Shellenberger Hall

on the KSU campus. The mill was subjected to heat treatment March 17-21, 2000.

The flour mill was heated using two portable steam heaters (Armstrong-Hunt, Inc., Three Rivers, MI) and a built-in steam heater.

The adult red flour beetles used in the experiments were two weeks old, of mixed sexes, reared on a diet of whole wheat flour plus 5% brewer's yeast and maintained at 28 degrees C (82.4

#### Pest Management



Dr. Bhadriraju  
Subramanyam

degrees F) with 65% relative humidity.

#### First Experiment

In the first experiment, a range of humidity levels was obtained using glycerol-water solutions in 43-liter plastic containers.

Different humidity levels were obtained by mixing glycerol and water (by volume) in the following proportions respectively: 50:50 ml; 65:35 ml; and 73:27 ml.

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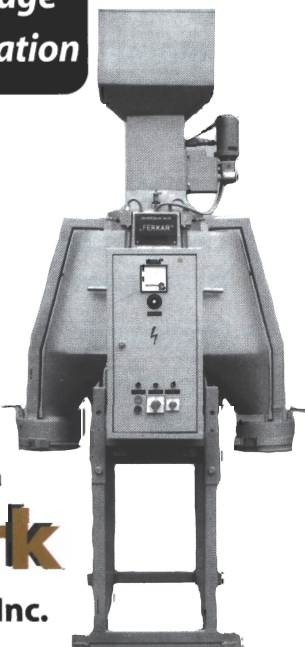
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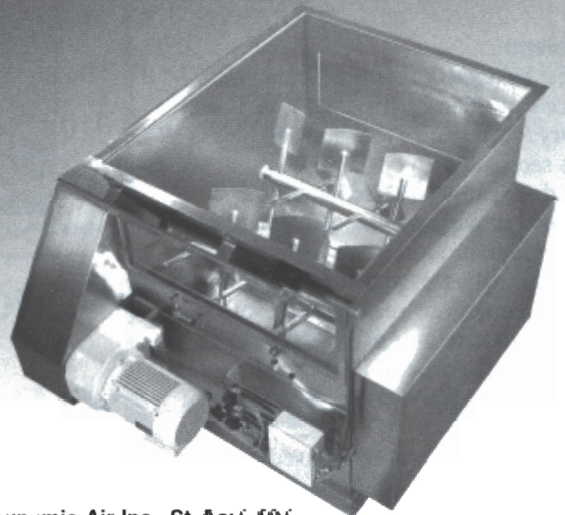
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In each plastic container, two liters of a glycerol/water mixture was introduced, and a wire mesh stand was placed above the mixture to hold 0.47-liter glass jars with insects. One of the containers was devoid of any solution.

Six glass jars, each containing 20 adult red flour beetles, were placed in each plastic container. Jars with similar numbers of adults were kept in the laboratory growth chamber to measure the insects' natural mortality.

Temperature and humidity inside containers and the growth chamber were recorded at 30-minute intervals using HOBO® temperature data loggers (Onset Computer Corp., Bourne, MA).

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The target temperature of 50 degrees C, which is necessary for an effective heat treatment, was not reached during the first 24 hours. This may explain the complete survival of the adult red flour beetles. After 47 hours, none of the adults survived the heat treatment at all humidity levels.

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Three of the six jars were sampled 24 hours after the heaters were turned on. The remaining three were sampled after 47 hours.

Jars removed during these two time periods were kept in a growth chamber for an additional 24 hours, before counting the numbers of live and dead adults.

#### Second Experiment

In the second experiment, the survival of adult red flour beetles at different humidity levels was determined when temperatures were stable between 50 degrees C (122 degrees F) and 52 degrees C (125.6 degrees F) during the flour mill heat treatment.

Humidity levels were established in plastic containers as described above. In each container, there were nine 0.47-liter jars, each holding 30 to 82 adults.

A similar number of jars were kept in a laboratory growth chamber to determine natural mortality. Survival of adults was observed after 20, 30, and 50 minutes by

sampling three jars from each container at each time period.

Adult survival was assessed after placing sampled jars for 24 hours in the growth chamber. The number of surviving adults out of the total exposed was expressed as a percentage.

#### Results of First Experiment

A broad range of humidity gradients was created with the glycerol solutions. In the first test, all adults survived 24 hours of exposure to the heat treatment at all humidity levels (see the table on page 38).

The target temperature of 50 degrees C, which is necessary for an effective heat treatment, was not reached during the first 24 hours. This may explain the complete survival of the adult red flour beetles.

After 47 hours, none of the adults survived the heat treatment at all humidity levels, because temperatures greater than 50 degrees C were maintained for 2.5 to four hours.

#### Results of Second Experiment

In the second experiment, survival of the red flour beetles at 50.1 degrees C ►

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## Experiment 1: Survival of Red Flour Beetle Adults at Different Humidity Levels After 24 and 47 hours During a Heat Treatment

Exposure Time (Hours)	Solution (% Glycerol)	Temp (°C)		Hours to Reach 50° C	Hours Above 50° C	Humidity (%)			Percent Survival
		Min	Max			Min	Max	Avg	
24	50	22.1	42.0	-	-	68.0	76.4	72.0	100
	65	22.1	42.0	-	-	55.4	60.5	58.6	100
	73	22.1	41.5	-	-	49.6	52.5	50.8	100
	No Solu.	22.1	41.5	-	-	24.0	39.1	30.7	100
47	50	22.1	51.8	43.0	4.0	55.6	76.4	70.7	0.0
	65	22.1	51.8	43.0	4.0	46.7	60.5	57.5	0.0
	73	22.1	50.7	44.5	2.5	33.8	52.5	49.3	0.0
	No Solu.	22.1	51.2	44.0	3.0	20.4	39.1	26.2	0.0

With regard to the solution, the total volume of the glycerol/water mixture was two liters per container. "No solu." refers to a container without any glycerol/water solution. The percent survival is an average of three subsamples, with 20 adults in each subsample. Only one adult died in the growth chamber at 28 degrees C and 65% humidity.

(122.18 degrees F) and 52.4 degrees C (126.36 degrees F) varied with the humidity level and exposure time.

All adults survived a 20-minute exposure at the humidity levels tested. The survival of adults exposed for 30 minutes at the humidity levels ranged from three to six.

After 30 minutes of exposure at 53.6% to 63.1% humidity, 71% of adults survived. This survival rate was higher than survival rates at other humidity levels.

A 50-minute exposure killed all adults at all humidity levels.

These results suggest that survival of adult red flour beetles is independent of the humidity level, if insects are exposed to temperatures equal to or greater than 50 degrees C for 50 minutes or more during heat treatment.

Past research with adult red flour beetles showed that at 50 degrees C, it takes 60 minutes to kill 99% of the adults.

The effectiveness of heat treatment is based on the premise that temperatures of 50 degrees C to 60 degrees C are maintained for at least 24 to 36 hours at all locations of the flour mill.

Therefore, maintaining temperatures of 50 to 60 degrees C for the required time

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## Experiment 2: Survival of Red Flour Beetle Adults Exposed to Different Humidity Levels for 20, 30 and 50 Minutes at 50.1 to 52.4° C During a Heat Treatment

Humidity (%)		Solution (% glycerol)	Percent Survival After		
Min	Max		20 minutes	30 minutes	50 minutes
53.6	63.1	50	100.0	71.0	0.0
46.1	49.3	65	100.0	6.2	0.0
31.6	48.1	73	100.0	2.7	0.0
20.4	20.5	No Solution	100.0	5.0	0.0

period at all locations in a mill is more critical than the humidity level for an effective heat treatment of stored-product insects.

### Future Work

It is difficult to conduct replicate trials in a mill, because the initial conditions and temperature profiles will be different each time a heat treatment is done.

Therefore, we are presently conduct-

Maintaining temperatures of 50 to 60 degrees C for the required time period at all locations in a mill is more critical than the humidity level for an effective heat treatment of stored-product insects.

ing replicated trials in laboratory growth chambers set at different temperatures and humidity levels using various insect species commonly associated with flour mills.

These results should provide additional information on the role of humidity in conferring survival to insects during a facility heat treatment.

While it took 43 hours to reach the required 50 degrees C in this experiment, this is not typical of a heat treatment. With most heat treatments, the proper temperature can be reached within 24 hours.

However, since the experiment began with insufficient heat energy, it took longer to reach the target temperature.

*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.*

*This chart shows the results of the second experiment, where the temperature was maintained between 50.1 degrees C and 52.4 degrees C. Note that in all cases, 100% of the adult red flour beetles were killed after 50 minutes of exposure. This suggests that the humidity level does not matter if the adult red flour beetle is exposed to temperatures equal to or greater than 50 degrees C for 50 minutes or more. The percent survival is based on an average of three subsamples, with 20 adults in each subsample.*

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