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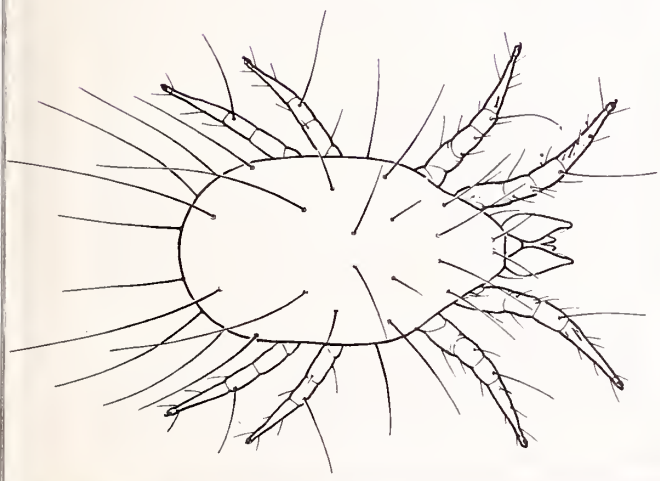
# Effects of Temperature and Humidity on Cheese Mites

## • With Review of Literature



U. S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division
in cooperation with
UNIVERSITY OF WISCONSIN
Agricultural Experiment Station

## PREFACE

In attempts to develop methods by which food products can be marketed free from contamination by insects, the Stored-Product Insects Branch of the Market Quality Research Division, Agricultural Marketing Service, has established several laboratories where insect preventive and control studies are conducted on many commodities. The mite studies on cheese are carried out at the Madison, Wis., field station. Much of the research conducted to date has involved the use of insecticides, including fumigants. However, there is an ever-increasing demand by the general public for the safer use--or even the elimination--of insecticides on or near food. The purpose of this study was to investigate in the laboratory the effects of some nonchemical treatments on mites infesting cheese.

The studies show that the two environmental factors of temperature and humidity can be regulated so as to be effective against mites. However, these same conditions that kill the mites also hinder proper flavor development or aging, and may cause cracking and loss of weight in cheddar cheese. For these reasons, controlled temperature and relative humidity may not be practical in storage warehouses or curing rooms, but they may be useful in other areas in processing and marketing channels. Followup studies need to be conducted on a larger scale before any recommendations can be made.

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# EFFECTS OF TEMPERATURE AND HUMIDITY ON CHEESE MITES

## With Review of Literature

by William L. Hilsenhoff and Robert J. Dicke[1]


## SUMMARY

Life history studies with Acarus siro L. and Tyrophagus putrescentiae (Schr.) on cheese showed that no eggs of either species of cheese mites hatched at 32° F., regardless of the relative humidity (r. h.). At 38° F., eggs that were incubated at a r. h. of 84, 92, or 100 percent hatched and developed to maturity. The average development time at 38° F. and 100 percent r. h. was 137 days for A. siro and 169 days for T. putrescentiae. Some eggs hatched at r. h. of 68 and 76 percent, but the larvae failed to develop to maturity.

Tests at 44°, 50°, and 56° F. showed that, as the temperature was raised, the length of time required for a mite to complete its life cycle was reduced. At 56° F. and 100 percent r. h., A. siro required only 26 days and T. putrescentiae 38 days. As the relative humidity at each temperature was decreased, the length of the life cycle of the mites was increased. Although a few eggs sometimes hatched at a r. h. as low as 48 percent, the resulting larvae seldom reached adulthood at a r. h. of less than 61 percent.

The rate of development of different individuals under the same conditions varied considerably. Mold growth also seemed to influence the rate of development to some extent. Typical approximate percentages of time spent in each stage of development were: Egg, 37 percent; larva, 16; resting larva, 7; protonymph, 12; resting protonymph, 7; deutonymph, 14; and resting deutonymph, 8 percent. A hypopus stage in the species studied was never encountered in any of the low-temperature tests and probably is very rare.

Survival tests with A. siro and T. putrescentiae on wood, wax, and cheese showed that, as the temperature was increased or the relative humidity decreased, the survival time was shortened. Relative humidities of 61 percent or less were definitely detrimental to cheese mite survival on wood or wax, even at the lower temperatures. On cheese, however, a r. h. of 43 percent or lower was necessary to cause complete mortality. T. putrescentiae was better able to survive under adverse conditions than was A. siro.

The egg-hatching tests showed that a decrease in temperature or in relative humidity reduced the viability and delayed the hatching of the eggs of A. siro. The same was true with T. putrescentiae, except that a r. h. of 84 percent, instead of 100 percent, was optimum for this species.

A final test conducted in large chambers in the laboratory to investigate the practicability of cheese mite control by lowering the relative humidity showed that a r. h. of 61 percent or lower was effective in killing exposed mites within 4 weeks. At these humidities, the mites could survive only in cracks beneath the waxed surface. Weight loss by the cheese at the lowest humidities was less than 1/2 of 1 percent in 4 weeks, indicating that moisture loss during this short period of storage would not be a serious problem in well-waxed cheese kept at these lower humidities.


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Since storage at low temperatures impairs flavor development of some cheese, and low humidities may cause cracking and some loss in weight, control of mites in warehouses by regulating these two environmental factors should not be attempted without further research. This does not preclude the possibility of their use as control measures under some circumstances, however, as they may be of some benefit in other areas in the processing and marketing channels.

## INTRODUCTION

Cheese mites are the most important arthropod pests of stored cheese. Most of the important species are in the families Acaridae, Glycyphagidae, and Carpoglyphidae. These mites attack all types of cheese that require aging or curing. Although the mites are very tiny, the tremendous numbers that are often present under conditions favorable to them can consume a considerable quantity of cheese. Infested cheese becomes unsightly and unsalable, and is subject to condemnation and confiscation by government inspectors. Control of cheese mites is essential to prevent such losses.

Prevention of mite infestation should be the first step in any mite control program. This is not easy, because cheese mites live not only on cheese, but on many other materials. Many species are important pests of stored grain. They have been found in the soil, in grain fields, in stable litter, in bird nests, on rodents, birds, and insects, and in almost any place that is moist enough to prevent their desiccation. They are carried into cheese warehouses on cheese, old cheese boxes, human clothing, and even other insects. Their entry would be difficult to detect because of their almost microscopic size. Some may even migrate unaided into the warehouse from a nearby grain field, bird nest, or rodent nest.

Sanitation is essential to any effective control program. Elimination of conditions under which mites might breed rapidly, and precautions to prevent mites from entering the warehouse will help keep down the mite population.

Cheese mites may be controlled in several ways, but so far no entirely satisfactory method has been found. The use of waxes or films on cheese in storage is standard, but it does not protect completely. Wax is the most commonly used covering, but it cracks easily, and this permits mites to enter and become established. Even a perfectly waxed cheese is not completely safe. Mites feed on the mold that grows on the surface of the wax. Given enough time, they can chew their way through the wax to the cheese.

Fumigation with methyl bromide is the only effective method of mite control presently used. An experienced fumigator can eliminate mites by this method, but often a warehouse is quickly reinfested and the fumigation must be repeated after only a few weeks. The main objection to fumigation is the sizable expense.

Insecticides provide many possibilities for control, but they have several drawbacks. An insecticide applied to shelves, floors, and walls of a warehouse could give effective, long-lasting, and inexpensive control. A rapidly detoxified insecticide applied to the waxed cheese could be very effective and inexpensive to apply. Perhaps an insecticide incorporated into the wax could be used. However, any insecticide used in mite control must give virtually 100-percent control, leave no toxic residues in the cheese, and impart no odors, off-flavors, or off-colors to the product. Considerable research is needed on this problem.

Environmental control has been considered as another possibility. At present, low-temperature storage of cheese is being used to give some measure of mite control, but no attempt is being made to control mites by lowering the relative humidity. The purpose of this study was to investigate the effects of temperature and relative humidity on cheese and cheese mites.

In this study, only Acarus siro L. and Tyrophagus putrescentiae (Schr.), the two most important cheese pest species in Wisconsin, were used. Only cheddar cheese was used in the experiments, because it is by far the most widely produced, and it is the type on which mite infestations are most common.

## MATERIALS AND METHODS

### Temperature Control

The temperature-control equipment consisted mostly of refrigerators. The main unit was a walk-in refrigerator, about 250 cubic feet in capacity. Any desired temperature below 60° F. could be maintained in this unit. A regular fluctuation every 50 minutes of ± 1° F. was caused by the cooling cycle, but the mean temperature remained nearly constant. The temperature fluctuation in the tightly closed humidity chambers was less than ± 1/2° F. from the mean, due to the rapidity of the temperature fluctuation in the circulating air outside the chambers.

A refrigerated fumigation chamber about 100 cubic feet in capacity also was used. This chamber had a fluctuation of ± 2° F., caused by a 15-minute cooling cycle. Because of the very rapid cycle, the temperature within the humidity chambers probably remained almost constant. To supplement the larger units, three ordinary household refrigerators were used. These held a fairly constant temperature, but were not as reliable as the larger units.

For experiments involving temperatures near or above room temperature, an electric oven was placed in the refrigerated fumigation chamber. This oven maintained a temperature within ± 1/2° F. of the desired mean.

### Humidity Control

Dilutions of sulfuric acid with water were used to control humidity. This method of humidity control is described quite thoroughly by Wilson (45)[2], Buxton (3), Buxton and Mellanby (4), Stokes and Robinson (43), and Solomon (40). Humidity chambers were constructed from 1/2-gallon ice cream cartons, 115 mm. in diameter. The top half of each carton was sawed off to leave a carton 115 mm. in height. This carton was then thoroughly waxed with paraffin. A crystallizing dish, 50 mm. high and 90 mm. in diameter, was embedded in wax in the bottom of each carton. This dish was filled with about 100 ml. of sulfuric acid solution calculated to give the desired relative humidity. The dish was covered with a piece of 1/4-inch mesh wire screen, on which the experimental material was placed. The top for the humidity chamber consisted of a clear plastic dish that fitted very tightly over the top of the carton. This plastic cover permitted observation of the experimental material without opening the humidity chamber.

Much larger humidity chambers were similarly constructed from 2-1/2-gallon ice cream cartons, waxed with paraffin. A larger crystallizing dish, 75 mm. high and 150 mm. in diameter, was embedded in wax in the bottom along one edge of each carton. Instead of a wire screen to support the experimental material, each large chamber had two pieces of 1/4-inch plywood. A piece 204 mm. long and 51 mm. wide was placed over the side of the crystallizing dish opposite the point that was in contact with the side of the carton. Another strip of plywood 140 mm. long and 32 mm. wide ran from the center of the first piece to the point where the dish contacted the side of the carton. The waxed lid of the carton served as the top for this larger humidity chamber.

[2] Underlined numbers in parentheses refer to items in Literature Cited, p. 42.

## Confinement Cylinders

To confine the mites to a test surface and yet allow air to reach the surface, small glass cylinders 19 mm. in height were used. These cylinders were cut from pyrex glass tubing of an inside diameter of 12 mm. The inner surface of each cylinder was ground with emery cloth until it was opaque and completely covered with very tiny particles of glass. The confinement cylinder was secured to the test surface with wax. Mites attempting to crawl out of such a cylinder would slip on the tiny glass particles and fall back onto the test surface. After use, each cylinder was thoroughly cleaned and reground before being used again. These cylinders were ground with an electric motor turning a shaft covered with very coarse emery cloth.[3]

## Species of Mites

Cultures of A. siro and T. putrescentiae were maintained on small cubes of cheddar cheese in the walk-in refrigerator. The high humidity in this refrigerator was ideal for mite rearing. All cultures were confined in ice cream cartons, the upper, inner edges of which were liberally coated with "Tangle foot"[4] to prevent escape of the mites. Flat 1/2-gallon cartons were used because of the ease with which blocks of cheese containing mites could be removed. To prevent mites from escaping through the bottom, the cartons were heavily waxed with cheese wax.

# EXPERIMENTS ON LIFE HISTORY

The effects of temperature and relative humidity on the life history of A. siro and T. putrescentiae were studied over a wide range of the temperatures and humidities that could occur in cheese warehouses.

## Procedure

A series of humidity chambers ranging from 22 to 100 percent r. h. was prepared and placed in refrigeration units of the desired temperatures. At least 2 days were allowed for the humidity in these chambers to come to equilibrium before any experimental material was placed in them.

Pieces of cheddar cheese, 83 mm. long, 51 mm. wide, and 25 mm. thick, were coated with cheese wax at 230-240° F. Eight circles of wax, 2 mm. in diameter, were cut from the top surface of each block of cheese. The wax was scored with a very small cork borer, and the wax within the circle was removed with a scalpel. Great care was taken not to cut the surface of the cheese, as this would cause cracks to develop in the cheese later on in the experiment. A confinement cylinder was attached around each circle of exposed cheese by heating one end of the cylinder for a few seconds, setting it in its proper place, and allowing it to cool. The wax was melted by the heat of the cylinder, and when it hardened again, it held the cylinder very securely.

For convenience, the circles of exposed cheese were arranged in two rows of four. In one row, 20 adult female A. siro were placed in each cylinder, and in the other, 20 adult female T. putrescentiae. This work was done in the walk-in refrigerator to prevent "oiling" of the cheese. Oiling occurs when natural oils exude from the cheese at temperatures in excess of about 60° F. Mites from a culture were picked up individually on the point of an insect pin and transferred to the cylinders. Care was taken not to transfer

[3] This method was developed by Hamilton Laudani, H. T. Vanderford, and C. D. Wooten at the Stored-Product Insects Laboratory in Savannah, Ga.

[4] Use of trade names is for identification purposes only and does not constitute endorsement by the U. S. Department of Agriculture.

eggs along with the mites. The mites were then held in the cylinders for 24 hours at 56° F. and 92 percent r. h. and allowed to lay eggs. After the egg-laying period, all mites were removed from the cylinders. Each block of cheese containing eggs was placed in a humidity chamber and incubated at the desired temperature and humidity. All cylinders were observed daily, and the number of mites in each life stage was recorded. Observations were continued until all mites had reached the adult stage or died.

## Results

The effects of temperature and relative humidity on the life history of A. siro and T. putrescentiae were pronounced. Lowering of either the temperature or the relative humidity tended to slow down or stop development in both species tested. No eggs of either species hatched at any humidity at 32° F. (data not shown in table). Eggs were incubated at this temperature for 180 days; when they were removed to a warmer temperature, they proved to be no longer viable. At a r. h. of about 45 percent or less and temperatures of 56° and 50° F., no eggs of either species hatched. At a r. h. of about 65 percent or less, the eggs of neither species hatched at temperatures of 44° and 38° F. When eggs did hatch at the lower humidities, the mites often did not survive, but died in the larval, larval resting, or protonymphal stage.

The results of the life history studies of A. siro and T. putrescentiae are summarized in tables 1 and 2 in the appendix, pages 15 to 18. Data for the 10 percent of the mite population that developed most slowly were excluded because abnormal mites often would fall into this group.

Individual mites varied considerably in rate of development. Sometimes there was a noticeable difference in development time from one replicate to another. In tables 1 and 2, the average length of time spent in each stage was calculated for the mites that developed most rapidly at each combination of temperature and humidity. Among the active feeding stages, the larval stage was usually longest and the protonymphal stage the shortest. The resting stages all required less time than any of the active feeding stages, and all appeared to last about the same length of time.

In calculations of average development time, the results from the four replicates at each combination of temperature and humidity were totaled to give the number of mites in each stage of development each day from the time the first egg hatched until all had become adults. The percent of mites in each stage, with respect to the total mites in all stages, was calculated for each day of development. The first day on which 90 percent of the mites reached a given stage of development was recorded for each life stage. This was also recorded for each 5-percent interval down to 5 percent. The amount of time spent in a given stage was found by subtracting the first day a given percentage of that stage was reached from the day the same percentage of the next succeeding stage was reached. The average development period for the first 90 percent of the mites is an average of the development periods at each 5-percent level up to and including the 90-percent level.

An example is the calculation of the average length of time the first 50 percent of A. siro spent in the deutonymph stage at 56° F. and 92 percent r. h. Table 3, on page 19, gives the percent of mites in each life stage on each day; this table shows that the first day on which 5 percent of the mites had reached the deutonymph stage was the 23rd day. Ten percent, as well as 15, 20, 25, and 30 percent, had reached this stage by the 24th day. On the 26th day, 5 percent of the mites had reached or passed the resting deutonymph stage, since, in these calculations, the percent of mites in any succeeding stage was added to the percent in the stage being determined. Thus, after 27 days, 10 percent were resting deutonymphs, and after 28 days, 15 and 20 percent had reached or passed the resting deutonymph stage. The same data presented under other circumstances are

shown in table 4 on page 19. The average for the first 10 percent would be the average of the 5- and 10-percent levels, or 3 days. The average for the first 50 percent would be the average of all the levels up to and including the 50-percent level, or 4.2 days.

The average amount of time spent in each life stage also was calculated for the first 50 percent and for the first 10 percent of the mites reaching each stage. The 50-percent level is probably the best indication of the proportionate amount of time spent in each stage. The 10-percent level is a measure of the potential speed of development at each combination of temperature and relative humidity.

A special procedure was used to calculate the length of time in the egg stage. Generally, between 25 and 75 eggs were laid in each cylinder, but many of these became hidden with mold, especially at the three higher relative humidities. Consequently, it was impossible to determine the total number of eggs or how many failed to hatch in each cylinder. The number of larvae present was recorded daily, and when there was no longer an increase in this number, all of the viable eggs were assumed to be hatched. The number of larvae present at this time was determined to be equal to the number of eggs that hatched. The number of eggs yet to hatch could then be calculated for each preceding day by subtracting the number of larvae present at that time from the number of eggs that eventually hatched.

Other corrections were necessary in the calculation of the time spent in the egg stage. Since the eggs were laid over a 24-hour period, they differed as much as 1 day in their age. The first 50 percent of the eggs that hatched were said to have been laid on day 0, and the latter 50 percent were said to have been laid on day 1.

Another correction for the length of time spent in the egg stage had to be made at combinations of temperature and relative humidity other than 56° F. and 92 percent r.h. Since all eggs were laid over a 24-hour period at this temperature and humidity, some of the eggs were incubated for up to 1 day before they were placed in the test temperature and relative humidity. The correction was often insignificant, and it was applied only when it amounted to more than half a day. To calculate this correction, the following formulas were used:

$$\text{correction} = X - b$$

$$X = \frac{X}{a} + (b-1) = \frac{(b-1)(a)}{(a-1)}$$

where $X$ = corrected period of development for the egg at the test temperature and humidity

$a$ = average development time for the egg at 56° F. and 92 percent r.h.

$b$ = most rapid observed development time for the egg at the test temperature and humidity

This correction applied completely only to those eggs that had developed for 1 day at 56° F. and 92 percent r.h. It applied to a varying extent to all eggs except those that had just been laid at the end of the oviposition period. If the correction were 3 days, 20 percent of the eggs would be said to have been laid on day -3, 20 percent on day -2, 20 percent on day -1, 20 percent on day 0, and 20 percent on day 1.

In the development cycle, the greatest percentage of time was spent in the egg stage. After incubation of the eggs, the tiny hexapod larvae emerged through a longitudinal slit. These larvae fed actively. As they increased in size, they became more and more rounded in appearance, and their backs became increasingly more strongly arched. Then feeding ceased and the larvae went into the quiescent larval resting stage. In this stage, these very much rounded forms were often found lying on their backs or sides, making absolutely no movement, and with the legs somewhat contracted. Upon ecdysis, a flattened,

octopod protonymph appeared and immediately began active feeding. Upon feeding, this form also became more and more arched until it, too, went into a resting stage. Ecdysis of this stage produced a deutonymph. No hypopial stages were ever encountered in any of these experiments, and only one A. siro hypopus was ever found in the cultures. The development of the deutonymph closely paralleled that of the protonymph.

Small deutonymphs could be distinguished from large protonymphs at this early stage of development only because the deutonymphs were still somewhat more flattened than the large protonymphs, which had become quite arched.

Adults, emerging from resting deutonymphs upon the final molt, could be easily distinguished from the other stages by the presence of genital organs. At all temperatures studied, copulation was noted in both species within 24 hours after the final molt.

## EXPERIMENTS ON SURVIVAL

These tests were to determine the ability of mites to survive under a wide range of combinations of temperature and relative humidity.

### Procedure

Experiments were set up on three different substrates--wood, wax, and cheese. These were conducted at 17 relative humidities, ranging from 6 to 100, at temperature intervals of 6° F. from 32° F. to 98° F. Because oiling takes place on cheese at about 60° F. and above, survival of mites on wax and cheese could be tested only at temperatures of 56° F. and lower. A. siro and T. putrescentiae were checked simultaneously in these experiments. Four confinement cylinders, each containing five mites, were used for each species at each temperature and humidity combination. Only adults and a few deutonymphs were used in these tests. The number of mites surviving was recorded daily for 12 days and after 2, 3, 4, and 5 weeks. A mite was considered dead only when incapable of any movement.

In the tests for survival on cheese, the blocks of cheese were exactly like those in the life history studies, except that a larger circle of wax, 4 mm. in diameter, was removed before attaching the confinement cylinder.

Cheese blocks for tests of survival on wax also were prepared exactly like those used in the life history studies, with one exception. No circle of wax was removed; the cylinders were attached to the unbroken waxed surface. In this test, no cheese was available to the mites as food.

Attaching confinement cylinders to wood needed a different technique. In tests at 62° F. and above, two rows of four cylinders were placed on a block of white pine wood, 76 mm. long, 51 mm. wide, and 19 mm. thick. A second block, of similar size and covered with felt, was placed on top of the cylinders, sandwiching them between the two blocks. This cylinder sandwich was held together by a rubber band. The bottom or test block was dipped briefly in paraffin at about 200° F., so that all the wood and just the bottom of the cylinders became coated with wax. After the wax had hardened for a few seconds, the rubber band was removed and the test block was ready for use. If wax seeped into any of the cylinders, the test block was rejected.

At temperatures of 56° F. and lower, the survival studies on wood were run at the same time and in the same humidity chambers as the survival studies on wax. Two small blocks, 60 mm. long, 19 mm. wide, and 25 mm. thick, were used instead of a larger block. The confinement cylinders were attached by the same method as they were to the larger blocks of wood, but only four cylinders were attached to each of the small blocks.

A small block with attached cylinders was then placed on each side of the waxed cheese block in the humidity chamber.

### Results

The results of these tests are contained in tables 5 through 11, on pages 20 to 34. An increase in temperature or a decrease in relative humidity decreased the survival of the cheese mites. The mites withstood lower humidities when in direct contact with the cheese than when placed on either wood or wax. Relative humidities of 61 percent or less, at cheese storage temperatures, were definitely detrimental to survival of cheese mites on wood or wax. Humidities of 43 percent or less caused complete mortality of mites in contact with the cheese. T. putrescentiae survived adverse conditions better than A. siro did.

## EXPERIMENTS ON EGG VIABILITY

To determine the effects of temperature and relative humidity on the viability of mite eggs, tests were set up at those combinations of temperature and relative humidity at which egg hatching was recorded in the life history studies.

### Procedure

Forty eggs of each species were incubated at each combination of temperature and relative humidity. Blocks of cheese of the same size as those used in the life history studies were waxed with black wax, which was prepared by adding finely divided carbon to regular cheese wax. Eggs deposited were readily visible against the black background. Two rows of four cylinders each were attached to the wax. In one row, 10 adult female A. siro were placed in each cylinder, and in the other, 10 adult female T. putrescentiae. These mites were allowed to lay eggs for 24 hours at 56° F. and 92 percent r. h. After this egg-laying period, all adult mites and all eggs except 10 were removed from each cylinder. The eggs on each cheese block were then incubated at the temperature and relative humidity to be tested. The cylinders were checked daily and the number of unhatched eggs recorded.

### Results

The results of this test are contained in table 12, page 35. Unfortunately, when this experiment was set up, tests could not be run simultaneously at 50° F. and 56° F. Tests at 38°, 44°, and 56° F. were set up at the same time, and the one at 50° F. was set up about a month later. The results of the tests set up at the same time showed that a decrease in temperature caused a decrease in egg viability and a delay in hatching. A decrease in relative humidity caused a delay in hatching and a decrease in viability in the eggs of A. siro. Relative humidities of 84 and 76 percent seemed to be optimum for T. putrescentiae.

As in the life history studies, a correction factor was calculated to compensate for partial incubation of the eggs at the oviposition temperature and humidity. In these experiments, the correction was calculated to be the average increase in incubation time. The formula used in the life history studies was altered to read:

$$\text{correction} = X - b$$

$$X = \frac{(b - 1/2)(2a)}{(2a - 1)}$$

where X = the corrected average incubation period for the test temperature and humidity

a = the average incubation period for the oviposition temperature and humidity

b = the observed average incubation period for the test temperature and humidity

The correction factor has not been applied to the figures in table 12, but is listed for each combination of temperature and relative humidity.

## EXPERIMENTS ON CONTROL WITH LOWERED HUMIDITY

This test was set up to determine whether cheese mites could be controlled by lowering the humidity.

### Procedure

In this test, small cheddars weighing about 500 grams each were cut from a larger cheddar, using a sharpened tin can. These small cheddars fit snugly, after waxing, in a pint ice cream carton. The small cheddars were waxed with black wax and double dipped at 230° to 240° F. Any cracks or holes in the wax coat were repaired with a small drop of wax and a spatula. The weight of each cheddar was recorded. One-half of the cheddars were placed in pint ice cream cartons, used to simulate cheese boxes. Twenty-six holes, made with a dissecting needle, were distributed evenly over the surface of each carton. The holes permitted some air circulation and also allowed mites to enter the carton as they could a cheese box. The rest of the cheddars were not put into the simulated cheese boxes.

The large humidity chambers were used in this experiment. About 500 ml. of sulfuric acid solution, calculated to give the desired humidity, was given 2 days to come to equilibrium with the air in the chamber. Relative humidities of 38 to 100 percent were tested at 56° F. A small unboxed cheddar was placed on one arm of the T made by the two strips of wood resting on the crystallizing dish, and a boxed cheddar on the other arm. A small cube of cheese on which were several thousand A. siro was placed at the base of the T, along with a similar cube on which were several thousand T. putrescentiae. After 4 weeks, the cheddars were removed, weighed, and checked for mite infestation.

### Results

The results of this test are shown in table 13, page 36. Relative humidities of 84 percent or more were highly favorable for the development of both species of cheese mites tested. At r. h. of 61 percent or less, mites survived only in cracks under the wax. Weight loss by the cheese, due to moisture loss, was negligible during the 4-week test period, even at the lower humidities. No correlation was apparent between weight loss and whether or not the cheese was in a carton during the experiment.

## DISCUSSION

In the life history studies of T. putrescentiae, the development times at the various humidities were almost the same at 44° F. and 50° F. A comparison with the development times of A. siro at various temperatures indicates that the development times for T. putrescentiae at 50° F. are somewhat longer than would be expected. This effect could not be caused, however, by incorrectly measured temperature or by an abnormal cheese substrate, since the tests with T. putrescentiae were run at the same time and on the same block of cheese as were those with A. siro, which behaved as anticipated. It is difficult to determine just what factor could have caused the results obtained. Perhaps a different strain of T. putrescentiae was used in the tests at 50° F. Another possibility

is that an adverse strain of mold was present in the tests at 50° F. A contributing factor to the situation was undoubtedly the fact that the tests involving T. putrescentiae at 50° F. were conducted in two parts. The egg-to-deutonymph development was checked at the same time as A. siro, but the deutonymph-to-adult development was checked in a different test. The substrate onto which these deutonymphs emerged was apparently not exactly to their liking, since the deutonymph part of the development cycle was abnormally long. This, however, would account for only part of the apparent discrepancy. It is possible that no discrepancy exists, but that T. putrescentiae reacts similarly to both 44° and 50° F.

Mold appears to affect the rate of development of mites. It was evident that the mites did eat mold when it was present, but that they could get along without it. At 68 percent r.h., no mold growth occurred, yet mites were able to complete their development cycle. Just the right amount of mold seemed to enhance the development of mites. Too much mold retarded the development of mites, probably because it prevented them from reaching the cheese, their main food source.

Another condition of the substrate that apparently affected the rate of development of mites was that caused by mites' previously having fed on it. A cheese surface that had been fed on before seemed more desirable than a freshly cut cheese surface. Perhaps for the same reason, several mites feeding in a given area tended to develop more rapidly than one or two isolated mites.

A comparison of results of the life history studies with those of other workers will not be attempted because of insufficient data on temperature and relative humidity in the literature. Another factor that makes comparison difficult is that most tests conducted by others were at higher temperatures and on grain or flour and not on cheese. It is generally agreed, however, that the lowering of temperature or relative humidity is unfavorable to mites and slows their rate of development.

Although mites of A. siro and T. putrescentiae were subjected to a wide range of combinations of temperature and humidity in the life history studies, not one hypopus was observed. Thousands of mites, perhaps even millions, were observed in the general cultures, yet only one hypopus was ever found in these cultures. This was a hypopus of A. siro. This form was extremely active and was constantly moving about through the other mites in the colony.

The literature on hypopus formation and the reasons for their formation is quite contradictory. Some species of mites are much more prone to hypopus formation than others. A. siro and T. putrescentiae are not noted for abundant hypopus formation. Polezhaev (24) subjected A. siro to many combinations of humidity and temperature and was unable to produce any hypopi. A. siro hypopi, as well as the hypopi of other species, seem to be generally associated with high temperatures and humidities. Cheese cannot be stored at high temperatures, and this probably accounts for the absence of hypopi on cheese.

The results of the egg-hatching tests conducted with T. putrescentiae showd that no eggs hatched at 44° or 38° F. Eggs of this species, at these temperatures, hatched at the four highest humidities tested in the life history studies. Eggs of both species hatched at some lower humidities in the life history studies than in the egg hatching studies. In the life history studies, a few of the eggs were deposited and incubated directly on cheese, while in the egg hatching tests all eggs were on wax. The higher humidity of the microclimate at the surface of the cheese could cause eggs deposited there to hatch when the general humidity in the chamber was lower. To explain why no eggs of T. putrescentiae hatched at 44° or 38° F. is rather difficult. Perhaps the black waxed cheese used in the egg hatching tests had some slight detrimental effect on the eggs. This, when combined with lowered temperatures or humidities, could have prevented the eggs from hatching. This would help to explain why the percentage of eggs hatching was lower than the 93 to 94 percent reported by Ihde (12). The fact that most of the eggs in the egg-hatching tests

were moved with an insect pin, while those in the life history studies were not touched, might also contribute to the differences in hatchability. The use of more than one strain of T. putrescentiae, or the physiological condition of the culture used, might help to explain the differences.

The egg-hatching tests show that the highest rate of hatching in A. siro takes place at 100 percent r. h., and decreases as the humidity is lowered. In T. putrescentiae, the greatest egg hatch occurred at 84 percent r. h. The lowest r. h. at which the eggs of either species hatched was 61 percent. These results closely parallel the findings of Kozulina (15).

The survival studies show that a r. h. of 68 percent or less is not conducive to mite survival. The reason for this is probably moisture loss through the integument. All of these mites respire through their integument, and drying of the integument would interfere with normal gas exchange and cause suffocation and death. As the temperature increases, so does the vapor pressure of water. This would cause more rapid dessication at higher temperatures, accounting for the fact that mites are better able to survive low humidity at lower temperatures. As the temperature decreases, the rate of metabolism in these cold-blooded creatures decreases, and this would explain the longer survival at lower temperatures, even at optimum humidities. In the survival tests, mites were better able to survive low humidities on cheese than on wax or wood. This was probably the result of a higher humidity in the microclimate above the cheese, or a result of additional moisture that was picked up from cheese eaten. There was undoubtedly no starvation effect, since the mites on wood or wax were able to survive a considerable period of time under optimum environmental conditions.

In the survival studies, only adult mites and a few deutonymphs were used. Except for the egg stage, these forms appeared to be the most hardy. The smaller forms were less resistant to adverse conditions. Resting stages seemed even more susceptible to adversity than were the active forms, but it was difficult to be certain of this since it was impossible to tell by observation just when a resting form was actually dead.

The results of these studies may have some interesting practical applications. It is thought that cheese warehouses may become mite infested through used cheese boxes that still contain mites. The results of the survival studies show this would be very unlikely if these empty boxes had been stored for even a short time at a low humidity. Almost any heated building in the winter time would have a relative humidity low enough to kill all of the mites in a few days. Daytime summer humidities also would be generally low enough to kill any exposed mites. Only where used cheese boxes had been stored in a humid enough place could mites from that source become a problem. The survival studies showed that cheese mites were well able to survive on wood in the absence of food for a fairly long time, providing the temperature and relative humidity were favorable.

The results of the experiments show that two environmental factors, low temperature and low humidity, might be useful in controlling mites in cheddar cheese, but both have undesirable features that might outweigh their ability to control mites. Also, since these methods have not been given a positive trial under actual cheese storage conditions, they might not be as effective as in the laboratory, so recommendations cannot be made at this time.

As the temperature is lowered, the rate of cheese mite development becomes slower and slower. Thus, the lower the temperature at which cheese is stored, the longer the period before the number of mites will make fumigation necessary. Life history studies show that at some temperatures between 38° and 32° F., none of the mite eggs hatch. A temperature of 32° F., therefore, would prevent any increase in mite population and should offer excellent control, but might affect the quality of the cheese. Only mites brought in from outside would be present in such a warehouse. They would survive a long time, but would produce no larvae as long as the cheese was held at 32° F. Fumigation probably would not be needed.

On the other hand, storage at low temperature impairs flavor development of the cheese. Practically no flavor development or aging takes place in cheddar cheese stored at 32° F. Also, at such low temperatures, evaporation is so slow that it is almost negligible. Thus, cheese stored at 32° F. would remain moist after a long period of storage. Maintaining a cheese warehouse at 32° F. would be more expensive than maintaining it at some higher temperature, especially during the heat of summer. This would be partly offset by the lower cost of maintaining a 32° F. temperature during the winter. Such costs would be more than compensated for if the need for fumigation were eliminated.

As relative humidity is lowered, the rate of development of the mites is decreased. This was indicated by the results of the survival studies and the life history studies. To further support these studies, the test with the very small cheddars showed that low humidities could kill mites. In this test, tremendous numbers of mites were placed next to the test cheese, but after 4 weeks, the only mites present on cheese at 61 percent r.h. or less were in cracks. Normal cheddars, especially younger ones, would not be nearly so likely to crack as the unbandaged small cheddars were. A warehouse or curing room maintained at a r.h. of 60 percent or less would probably remain free from significant mite infestations.

During the winter, a r.h. of 60 percent is normal in shelf-curing rooms maintained at 56° F. Relative humidities between 70 and 80 percent were most common in storage warehouses where the temperature ranged from 40° to 45° F. During the summer, the r.h. in the curing rooms and warehouses was generally between 80 and 90 percent.

Low humidity might cause an undesirable checking of the cheese. The question is, would a r.h. of 60 percent be so low as to cause serious checking, especially if the cheese had been well waxed? The test with the small cheddars showed that moisture loss was negligible during 4 weeks at humidities even less than 60 percent, and these cheddars had a much greater surface-to-volume ratio than a normal-sized cheddar.

Before control by low humidity can be recommended, one must consider whether the possibility of damage to the cheese, plus the cost of buying and operating equipment to maintain low humidity to control mites, would be offset by the elimination of fumigation costs. In a shelf-curing room, humidity would probably not be hard to control, but in a cheese warehouse, where cheeses are packed close together and stacked to the ceiling, it might be difficult to lower the humidity among the piles of cheese.

To test the assumption that mite control is possible in a cheese curing room by maintaining a r.h. of 60 percent, observations of mite populations and r.h. readings were made in cheese warehouses at 4-month intervals, Mite populations on cheddars being shelf-cured at 56° F. had reached a point in mid-November where fumigation was necessary. In mid-March, 4 months after fumigation, no mites were found on cheese in this curing room. The r.h. was about 60 percent. By mid-July, a very large mite population was again present, making fumigation necessary. The r.h. was about 80 percent. This seasonal fluctuation in humidity was as might be expected, since during the winter the absolute humidity of the outside air is much lower than in the summer.

If the disadvantages can be overcome, two possibilities for effective control of mites are indicated--a temperature of 32° F. or a r.h. of 60 percent or less. Control with temperature would apply only to cheese warehouses. It is possible that mite control with low humidities could be used in both warehouses and shelf-curing rooms, but would probably be most effective in the latter. Studies on a larger scale must be conducted before recommendations can be made.

# APPENDIX

## Tables

TABLE 1.--Average number of days spent in each stage of development by the first 10, 50, and 90 percent of Acarus siro that showed the maximum growth rate

| Relative humidity | Maximum number of mites observed | Mites becoming adults | Mites completing a given stage of development | Average number of days in each stage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Egg | Larva | Resting larva | Proto-nymph | Resting protonymph | Deuto-nymph | Resting deutonymph | Total |
| Percent | Number | Number | Percent | Days | Days | Days | Days | Days | Days | Days | Days |
| | | | | 56° F. | | | | | | | |
| 100 | 54 | 30 | 10 | 11.0 | 4.5 | 1.5 | 2.0 | 1.5 | 3.5 | 1.0 | 25.0 |
| | | | 50 | 11.2 | 5.2 | 1.9 | 2.2 | 1.2 | 2.8 | 1.8 | 26.3 |
| | | | 90 | 11.5 | 5.5 | 1.9 | 2.3 | 1.3 | 2.4 | 2.3 | 27.2 |
| 92 | 114 | 114 | 10 | 12.0 | 4.0 | 2.5 | 3.0 | 2.0 | 3.0 | 2.5 | 29.0 |
| | | | 50 | 12.1 | 4.7 | 2.2 | 3.2 | 2.2 | 4.2 | 2.6 | 31.2 |
| | | | 90 | 12.2 | 5.1 | 2.2 | 4.0 | 2.2 | 4.6 | 2.6 | 32.9 |
| 84 | 57 | 33 | 10 | 12.0 | 5.0 | 3.0 | 2.0 | 2.0 | 4.5 | 2.5 | 31.0 |
| | | | 50 | 12.8 | 5.8 | 2.0 | 3.5 | 1.9 | 3.9 | 2.6 | 32.5 |
| | | | 90 | 13.5 | 6.9 | 2.8 | 3.2 | 2.3 | 3.8 | 2.7 | 35.2 |
| 76 | 87 | 27 | 10 | 12.0 | 4.0 | 3.0 | 3.5 | 2.0 | 5.0 | 3.0 | 32.5 |
| | | | 50 | 12.6 | 7.3 | 2.1 | 4.1 | 2.0 | 5.0 | 2.9 | 36.0 |
| | | | 90 | 12.4 | 9.3 | 2.0 | 4.5 | 2.3 | 4.9 | 2.9 | 38.3 |
| 68 | 54 | 36 | 10 | 12.0 | 8.5 | 3.0 | 3.5 | 3.0 | 4.5 | 2.5 | 37.0 |
| | | | 50 | 12.7 | 10.2 | 3.0 | 4.6 | 2.5 | 5.3 | 2.7 | 41.0 |
| | | | 90 | 12.7 | 12.9 | 3.1 | 4.7 | 2.6 | 6.3 | 3.0 | 45.3 |
| 61 | 19 | 5 | 10 | 12.0 | 8.0 | 2.0 | 4.5 | 1.5 | 4.0 | 3.0 | 35.0 |
| | | | 50 | 14.0 | 6.8 | 3.1 | 5.2 | 2.2 | 3.1 | 2.4 | 36.8 |
| | | | 90 | 14.4 | 10.4 | 1.7 | 3.7 | 1.4 | 3.5 | 2.8 | 37.9 |
| 54 | 6 | 0 | 10 | 19.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 19.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 19.0 | died | --- | --- | --- | --- | --- | --- |
| 48 and below - no eggs hatched | | | -- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 50° F. | | | | | | | |
| 100 | 73 | 67 | 10 | 16.5 | 7.0 | 2.5 | 4.0 | 2.0 | 6.5 | 3.0 | 41.5 |
| | | | 50 | 17.2 | 7.6 | 3.4 | 3.8 | 3.5 | 5.9 | 3.3 | 44.5 |
| | | | 90 | 18.2 | 8.5 | 4.0 | 4.7 | 3.4 | 6.9 | 3.4 | 49.1 |
| 92 | 85 | 84 | 10 | 16.5 | 6.5 | 3.0 | 4.0 | 2.0 | 6.5 | 4.0 | 42.5 |
| | | | 50 | 16.6 | 7.5 | 3.3 | 4.0 | 2.5 | 6.8 | 4.1 | 44.8 |
| | | | 90 | 17.2 | 8.1 | 3.6 | 4.5 | 2.6 | 7.5 | 4.1 | 47.6 |
| 84 | 58 | 55 | 10 | 17.5 | 8.5 | 3.0 | 4.0 | 3.5 | 5.0 | 4.0 | 45.5 |
| | | | 50 | 18.2 | 10.5 | 3.8 | 4.4 | 3.2 | 5.5 | 4.0 | 49.6 |
| | | | 90 | 19.4 | 11.3 | 3.8 | 4.9 | 3.1 | 5.7 | 4.1 | 52.3 |
| 76 | 77 | 33 | 10 | 17.0 | 8.0 | 4.0 | 4.0 | 3.0 | 6.0 | 3.5 | 45.5 |
| | | | 50 | 17.0 | 13.5 | 4.0 | 5.5 | 2.6 | 4.3 | 3.3 | 50.2 |
| | | | 90 | 17.0 | 20.0 | 4.6 | 5.8 | 2.9 | 5.8 | 3.8 | 59.9 |
| 68 | 66 | 46 | 10 | 18.0 | 10.0 | 4.5 | 7.0 | 3.5 | 6.5 | 4.0 | 53.5 |
| | | | 50 | 17.5 | 15.9 | 4.7 | 5.4 | 3.3 | 6.3 | 4.2 | 57.3 |
| | | | 90 | 18.0 | 19.9 | 4.6 | 5.4 | 3.2 | 5.9 | 3.9 | 60.9 |
| 61 | 1 | 0 | 10 | 24.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 23.6 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 23.1 | died | --- | --- | --- | --- | --- | --- |
| 54 | 18 | 3 | 10 | 24.0 | 22.0 | 4.0 | 5.0 | 4.0 | 8.0 | 4.0 | 71.0 |
| | | | 50 | 24.0 | 24.1 | 3.2 | 4.5 | 3.9 | 8.4 | 3.8 | 71.9 |
| | | | 90 | 23.8 | 28.8 | 2.0 | 4.1 | 2.9 | 7.4 | 3.7 | 72.7 |
| 48 | 5 | 0 | 10 | 24.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 24.2 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 23.8 | died | --- | --- | --- | --- | --- | --- |
| 43 and below - no eggs hatched | | | -- | --- | --- | --- | --- | --- | --- | --- | --- |

TABLE 1.--Average number of days spent in each stage of development by the first 10, 50, and 90 percent of Acarus siro that showed the maximum growth rate--Continued

| Relative humidity | Maximum number of mites observed | Mites becoming adults | Mites completing a given stage of development | Average number of days in each stage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Egg | Larva | Resting larva | Proto-nymph | Resting protonymph | Deuto-nymph | Resting deutonymph | Total |
| Percent | Number | Number | Percent | Days | Days | Days | Days | Days | Days | Days | Days |
| | | | | | | 44° F. | | | | | |
| 100 | 78 | 56 | 10 | 25.0 | 10.5 | 4.5 | 6.5 | 3.0 | 6.5 | 5.0 | 61.0 |
| | | | 50 | 25.0 | 12.0 | 4.4 | 6.4 | 3.7 | 6.0 | 5.7 | 63.2 |
| | | | 90 | 26.4 | 12.2 | 4.9 | 6.6 | 3.2 | 6.9 | 5.7 | 65.9 |
| 92 | 72 | 70 | 10 | 29.5 | 12.5 | 4.5 | 5.5 | 4.0 | 6.5 | 6.5 | 69.0 |
| | | | 50 | 31.8 | 11.5 | 4.9 | 5.9 | 3.5 | 8.3 | 5.6 | 71.5 |
| | | | 90 | 34.2 | 10.8 | 4.6 | 5.7 | 4.1 | 9.0 | 5.7 | 74.1 |
| 84 | 160 | 159 | 10 | 29.0 | 13.0 | 4.0 | 6.5 | 3.5 | 6.5 | 6.0 | 68.5 |
| | | | 50 | 30.7 | 12.5 | 4.2 | 6.2 | 3.3 | 7.8 | 5.8 | 70.5 |
| | | | 90 | 32.6 | 11.6 | 4.4 | 6.1 | 3.9 | 8.6 | 6.1 | 73.3 |
| 76 | 88 | 50 | 10 | 26.5 | 16.0 | 7.0 | 9.0 | 4.5 | 15.0 | 6.0 | 84.0 |
| | | | 50 | 27.8 | 18.3 | 6.4 | 9.1 | 6.6 | 14.3 | 6.1 | 88.6 |
| | | | 90 | 28.8 | 20.9 | 6.1 | 10.3 | 7.2 | 14.8 | 7.3 | 95.4 |
| 68 | 6 | 0 | 10 | 33.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 34.3 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 35.2 | died | --- | --- | --- | --- | --- | --- |
| 61 and below - no eggs hatched | | | -- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | | 38° F. | | | | | |
| 100 | 48 [1] (40) | [2] (40) | 10 | 58.5 | 21.5 | 8.0 | 10.0 | 4.0 | 17.5 | 11.0 | 130.5 |
| | | | 50 | 59.1 | 23.1 | 8.0 | 9.8 | 5.6 | 20.9 | 10.4 | 136.9 |
| | | | 90 | 61.5 | 24.6 | 8.6 | 9.9 | 5.2 | 23.6 | 11.1 | 144.5 |
| 92 | 58 [1] (40) | [2] (43) 34 | 10 | 62.0 | 21.0 | 8.5 | 12.0 | 5.5 | 19.5 | 11.5 | 140.0 |
| | | | 50 | 65.2 | 21.1 | 9.6 | 10.8 | 7.3 | 22.9 | 10.3 | 147.2 |
| | | | 90 | 65.4 | 23.6 | 10.8 | 11.7 | 5.9 | 24.8 | 10.2 | 152.4 |
| 84 | 79 [1] (40) | [2] (64) 24 | 10 | 70.0 | 17.5 | 9.0 | 11.0 | 7.5 | 36.0 | 7.5 | 158.5 |
| | | | 50 | 70.3 | 18.6 | 8.9 | 13.3 | 6.5 | 41.1 | 9.8 | 168.5 |
| | | | 90 | 71.6 | 21.7 | 10.3 | 14.1 | 6.5 | 46.0 | 8.7 | 178.9 |
| 76 | 34 | 0 | 10 | 72.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 71.1 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 70.4 | died | --- | --- | --- | --- | --- | --- |
| 68 | 3 | 0 | 10 | 79.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 77.8 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 77.4 | died | --- | --- | --- | --- | --- | --- |
| 61 and below - no eggs hatched | | | -- | --- | --- | --- | --- | --- | --- | --- | --- |

[1] The lengths of the deutonymph and resting deutonymph stages were determined separately. The figure in parentheses represents the number of resting protonymphs used for this determination.
[2] Represents the number of mites reaching the deutonymph stage.

TABLE 2.--Average number of days spent in each stage of development by the first 10, 50, and 90 percent of Tyrophagus putrescentiae that showed the maximum growth rate

| Relative humidity | Maximum number of mites observed | Mites becoming adults | Mites completing a given stage of development | Average number of days in each stage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Egg | Larva | Resting larva | Proto-nymph | Resting protonymph | Deuto-nymph | Resting deutonymph | Total |
| Percent | Number | Number | Percent | Days | Days | Days | Days | Days | Days | Days | Days |
| | | | | 56° F. | | | | | | | |
| 100 | 28 | 15 | 10 | 12.5 | 6.0 | 2.5 | 4.0 | 2.5 | 6.0 | 3.0 | 36.5 |
| | | | 50 | 13.4 | 7.6 | 2.2 | 5.4 | 1.6 | 5.8 | 2.3 | 38.3 |
| | | | 90 | 13.3 | 9.9 | 1.8 | 5.3 | 2.1 | 7.8 | 2.7 | 42.9 |
| 92 | 74 | 46 | 10 | 12.5 | 6.0 | 2.0 | 4.0 | 1.5 | 6.0 | 3.5 | 35.5 |
| | | | 50 | 13.1 | 6.6 | 2.1 | 4.7 | 2.3 | 7.3 | 2.6 | 38.7 |
| | | | 90 | 13.6 | 7.1 | 2.1 | 5.8 | 2.4 | 7.6 | 2.5 | 41.1 |
| 84 | 117 | 60 | 10 | 13.5 | 7.0 | 2.0 | 5.0 | 2.5 | 7.0 | 3.0 | 40.0 |
| | | | 50 | 13.9 | 7.6 | 2.6 | 5.1 | 2.5 | 7.5 | 3.2 | 42.4 |
| | | | 90 | 14.2 | 8.6 | 2.9 | 5.8 | 2.9 | 8.2 | 2.9 | 45.5 |
| 76 | 104 | 29 | 10 | 13.0 | 8.0 | 4.0 | 3.5 | 2.0 | 5.0 | 2.5 | 38.0 |
| | | | 50 | 13.7 | 10.2 | 3.2 | 3.7 | 2.2 | 5.3 | 2.7 | 41.0 |
| | | | 90 | 13.7 | 12.2 | 3.5 | 3.9 | 2.0 | 5.3 | 2.9 | 43.5 |
| 68 | 53 | 18 | 10 | 13.0 | 10.5 | 2.5 | 5.0 | 1.5 | 6.0 | 3.0 | 41.5 |
| | | | 50 | 13.5 | 12.1 | 2.7 | 4.8 | 1.9 | 5.4 | 3.2 | 43.6 |
| | | | 90 | 13.7 | 14.0 | 2.6 | 4.1 | 2.1 | 5.6 | 3.3 | 45.4 |
| 61 | 81 | 14 | 10 | 13.5 | 9.5 | 2.5 | 4.0 | 2.0 | 4.5 | 2.5 | 38.5 |
| | | | 50 | 14.1 | 11.2 | 3.8 | 3.4 | 2.0 | 4.8 | 2.8 | 42.1 |
| | | | 90 | 14.3 | 13.4 | 4.8 | 3.1 | 2.0 | 4.7 | 2.9 | 45.2 |
| 54 | 30 | 0 | 10 | 15.5 | 18.5 | 4.0 | died | --- | --- | --- | --- |
| | | | 50 | 16.5 | 17.5 | 4.0 | died | --- | --- | --- | --- |
| | | | 90 | 17.1 | 19.1 | 2.2 | died | --- | --- | --- | --- |
| 48 | 10 | 0 | 10 | 16.0 | 12.0 | died | --- | --- | --- | --- | --- |
| | | | 50 | 16.4 | 15.7 | died | --- | --- | --- | --- | --- |
| | | | 90 | 17.1 | 16.3 | died | --- | --- | --- | --- | --- |
| 43 and below - no eggs hatched -- | | | | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 50° F. | | | | | | | |
| 100 | 47 [1] (38) | [2] (39) 22 | 10 | 27.5 | 15.0 | 7.0 | 10.5 | 6.5 | 17.0 | 8.0 | 91.5 |
| | | | 50 | 27.9 | 16.7 | 6.3 | 11.4 | 5.4 | 19.1 | 8.0 | 94.8 |
| | | | 90 | 28.4 | 17.8 | 6.2 | 12.1 | 4.6 | 22.2 | 8.9 | 100.2 |
| 92 | 72 [1] (39) | [2] (25) 24 | 10 | 28.0 | 15.5 | 6.5 | 12.0 | 5.0 | 17.5 | 6.5 | 91.0 |
| | | | 50 | 28.9 | 16.1 | 7.9 | 10.8 | 4.4 | 19.0 | 6.6 | 93.7 |
| | | | 90 | 29.7 | 17.4 | 7.9 | 10.7 | 4.5 | 21.9 | 5.7 | 97.8 |
| 84 | 81 [1] (41) | [2] (10) 11 | 10 | 28.0 | 15.5 | 8.0 | 11.5 | 4.0 | 17.0 | 11.0 | 95.0 |
| | | | 50 | 28.4 | 18.0 | 9.5 | 12.4 | 5.8 | 18.7 | 12.3 | 105.1 |
| | | | 90 | 29.2 | 21.4 | 9.0 | 11.8 | 6.4 | 22.4 | 12.1 | 112.3 |
| 76 | 90 [1] (40) | [2] (11) 10 | 10 | 29.5 | 14.0 | 6.5 | 9.5 | 6.5 | 15.0 | 7.0 | 88.0 |
| | | | 50 | 30.2 | 15.3 | 9.4 | 8.6 | 5.4 | 17.0 | 12.6 | 98.5 |
| | | | 90 | 30.5 | 20.1 | 8.9 | 6.6 | 5.2 | 24.6 | 11.3 | 107.2 |
| 68 | 73 [1] (40) | [2] (17) 9 | 10 | 31.0 | 14.5 | 6.0 | 10.0 | 4.5 | 16.0 | 11.0 | 93.0 |
| | | | 50 | 31.8 | 16.7 | 7.5 | 10.0 | 6.4 | 20.0 | 12.2 | 104.6 |
| | | | 90 | 32.1 | 18.7 | 7.6 | 9.9 | 7.4 | 28.0 | 9.9 | 113.6 |
| 61 | 27 | 0 | 10 | 31.0 | 28.0 | died | --- | --- | --- | --- | --- |
| | | | 50 | 31.9 | 26.7 | died | --- | --- | --- | --- | --- |
| | | | 90 | 32.5 | 27.3 | died | --- | --- | --- | --- | --- |
| 54 | 31 | 0 | 10 | 30.0 | 22.0 | died | --- | --- | --- | --- | --- |
| | | | 50 | 30.5 | 23.3 | died | --- | --- | --- | --- | --- |
| | | | 90 | 30.7 | 25.6 | died | --- | --- | --- | --- | --- |
| 48 | 49 | 0 | 10 | 30.0 | 13.0 | died | --- | --- | --- | --- | --- |
| | | | 50 | 30.2 | 18.6 | died | --- | --- | --- | --- | --- |
| | | | 90 | 30.4 | died | --- | --- | --- | --- | --- | --- |
| 43 and below - no eggs hatched -- | | | | --- | --- | --- | --- | --- | --- | --- | --- |

TABLE 2.--Average number of days spent in each stage of development by the first 10, 50, and 90 percent of Tyrophagus putrescentiae that showed the maximum growth rate--Continued

| Relative humidity | Maximum number of mites observed | Mites becoming adults | Mites completing a given stage of development | Average number of days in each stage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Egg | Larva | Resting larva | Proto-nymph | Resting protonymph | Deuto-nymph | Resting deutonymph | Total |
| Percent | Number | Number | Percent | Days | Days | Days | Days | Days | Days | Days | Days |
| | | | | 44° F. | | | | | | | |
| 100 | 14 | 8 | 10 | 25.0 | 19.0 | 9.0 | 11.0 | 5.0 | 12.0 | 3.5 | 84.5 |
| | | | 50 | 30.2 | 19.3 | 6.3 | 13.9 | 5.1 | 11.2 | 5.6 | 91.6 |
| | | | 90 | 30.9 | 22.2 | 6.4 | 13.3 | 4.7 | 13.4 | 5.4 | 96.3 |
| 92 | 14 | 10 | 10 | 33.0 | 13.0 | 6.0 | 8.5 | 4.5 | 9.0 | 7.0 | 83.0 |
| | | | 50 | 33.6 | 15.3 | 5.9 | 7.5 | 5.8 | 12.3 | 7.8 | 88.2 |
| | | | 90 | 33.5 | 17.6 | 4.8 | 12.0 | 4.9 | 13.0 | 7.8 | 93.6 |
| 84 | 10 | 4 | 10 | 33.0 | 17.0 | 3.0 | 12.0 | 5.0 | 14.0 | 6.0 | 90.0 |
| | | | 50 | 33.1 | 18.5 | 2.2 | 13.0 | 5.1 | 13.8 | 6.9 | 92.6 |
| | | | 90 | 34.2 | 19.8 | 3.4 | 13.0 | 5.7 | 10.9 | 7.4 | 94.4 |
| 76 | 10 | 3 | 10 | 33.0 | 21.0 | 9.0 | 14.0 | 7.0 | 13.0 | 7.0 | 104.0 |
| | | | 50 | 32.9 | 22.0 | 13.5 | 9.0 | 5.8 | 21.4 | 6.6 | 111.2 |
| | | | 90 | 34.2 | 25.4 | 13.9 | 13.9 | 6.9 | 18.0 | 7.7 | 120.0 |
| 68 and below - no eggs hatched -- | | | | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 38° F. | | | | | | | |
| 100 | 35 [1] (40) | [2] (26) 18 | 10 | 63.0 | 28.5 | 7.0 | 15.5 | 7.0 | 26.0 | 17.5 | 164.5 |
| | | | 50 | 63.7 | 28.9 | 8.9 | 15.3 | 5.8 | 29.2 | 16.9 | 168.7 |
| | | | 90 | 63.8 | 30.7 | 8.7 | 14.8 | 7.6 | 31.1 | 16.3 | 173.0 |
| 92 | 59 [1] (38) | [2] (7) 16 | 10 | 72.0 | 30.0 | 8.0 | 14.5 | 3.5 | 42.0 | 17.0 | 187.0 |
| | | | 50 | 72.6 | 33.4 | 9.8 | 20.5 | 9.5 | 36.5 | 16.6 | 198.9 |
| | | | 90 | 73.7 | 36.3 | 9.4 | 23.6 | 8.4 | 36.8 | 16.2 | 204.4 |
| 84 | 52 [1] (41) | [2] (30) 14 | 10 | 76.5 | 27.5 | 7.5 | 15.0 | 11.0 | 46.0 | 14.0 | 197.5 |
| | | | 50 | 76.7 | 29.9 | 9.2 | 18.7 | 8.8 | 46.1 | 13.1 | 202.5 |
| | | | 90 | 78.1 | 31.6 | 8.8 | 20.4 | 8.6 | 46.2 | 12.6 | 206.3 |
| 76 | 4 | 0 | 10 | 79.0 | died | --- | --- | --- | --- | --- | --- |
| | | | 50 | 77.8 | died | --- | --- | --- | --- | --- | --- |
| | | | 90 | 77.4 | died | --- | --- | --- | --- | --- | --- |
| 68 and below - no eggs hatched -- | | | | --- | --- | --- | --- | --- | --- | --- | --- |

[1] The lengths of the deutonymph and resting deutonymph stages were determined separately. The figure in parentheses represents the number of resting protonymphs used for this determination.
[2] Represents the number of mites reaching the deutonymph stage.

TABLE 3.--Proportion of Acarus siro in each of several life stages on a given number of days after hatching

| Days | Percentage in life stage | | |
|---|---|---|---|
| | Deutonymph | Resting deutonymph | Adult |
| Number | Percent | Percent | Percent |
| 22 | 2 | --- | --- |
| 23 | 9 | --- | --- |
| 24 | 34 | --- | --- |
| 25 | 47 | 1 | --- |
| 26 | 54 | 4 | 1 |
| 27 | 58 | 11 | 1 |
| 28 | 59 | 18 | 4 |
| 29 | 44 | 32 | 6 |
| 30 | 35 | 35 | 17 |

TABLE 4.--Time taken for given percentages of Acarus siro to reach the deutonymphal and resting deutonymphal stages, and time spent in the deutonymphal stage

| Mites | Time taken-- | | |
|---|---|---|---|
| | To reach deutonymphal stage | In deutonymphal stage | To reach resting deutonymphal stage |
| Percent | Days | Days | Days |
| 5 | 23 | 3 | 26 |
| 10 | 24 | 3 | 27 |
| 15 | 24 | 4 | 28 |
| 20 | 24 | 4 | 28 |
| 25 | 24 | 5 | 29 |
| 30 | 24 | 5 | 29 |
| 35 | 25 | 4 | 29 |
| 40 | 25 | 5 | 30 |
| 45 | 25 | 5 | 30 |
| 50 | 26 | 4 | 30 |

TABLE 5.--Mortality of *Acarus siro* on wood exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 1 day | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 0 | 0 | 0 | 5 | 0 | 10 | 0 | 0 | 0 | 0 | 60 | 100 |
| 92 | 9 | 0 | 0 | 0 | 0 | 5 | 0 | 20 | 10 | 35 | 95 | 100 |
| 84 | 0 | 0 | 5 | 0 | 0 | 25 | 10 | 80 | 65 | 100 | 100 | 100 |
| 76 | 0 | 0 | 0 | 0 | 10 | 42 | 95 | 100 | 61 | 100 | 100 | 100 |
| 68 | 0 | 0 | 0 | 16 | 5 | 83 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 0 | 0 | 0 | 0 | 80 | 68 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 0 | 0 | 0 | 0 | 35 | 76 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 0 | 0 | 10 | 14 | 10 | 90 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 0 | 0 | 0 | 0 | 10 | 92 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 5 | 0 | 10 | 20 | 24 | 96 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 5 | 0 | 9 | 15 | 25 | 95 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 9 | 0 | 5 | 29 | 21 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 0 | 0 | 10 | 0 | 37 | 89 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 5 | 0 | 10 | 35 | 26 | 92 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 0 | 0 | 10 | 35 | 24 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 0 | 0 | 25 | 45 | 24 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 0 | 0 | 20 | 20 | 29 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | After 3 days | | | | | | | | | | | |
| 100 | 5 | 5 | 0 | 5 | 0 | 10 | 0 | 0 | 9 | 5 | 100 | 100 |
| 92 | 14 | 16 | 0 | 5 | 17 | 5 | 0 | 20 | 19 | 60 | 100 | 100 |
| 84 | 0 | 10 | 9 | 65 | 21 | 58 | 10 | 80 | 95 | 100 | 100 | 100 |
| 76 | 17 | 16 | 55 | 60 | 43 | 96 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 24 | 23 | 62 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 15 | 20 | 77 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 30 | 33 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 38 | 35 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 55 | 55 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 30 | 28 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 57 | 30 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 38 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 62 | 60 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 68 | 53 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 50 | 35 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 60 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 75 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 5.--Mortality of Acarus siro on wood exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 5 days | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 10 | 50 | 0 | 5 | 5 | 10 | 0 | 15 | 26 | 25 | 100 | 100 |
| 92 | 14 | 69 | 0 | 5 | 17 | 9 | 0 | 25 | 48 | 60 | 100 | 100 |
| 84 | 5 | 55 | 24 | 70 | 21 | 58 | 10 | 85 | 95 | 100 | 100 | 100 |
| 76 | 30 | 74 | 100 | 65 | 48 | 96 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 62 | 95 | 100 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 60 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 65 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 67 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 85 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 67 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | After 7 days | | | | | | | | | | | |
| 100 | 10 | 90 | 0 | 5 | 10 | 20 | 20 | 20 | 39 | 70 | 100 | 100 |
| 92 | 14 | 100 | 0 | 5 | 22 | 19 | 25 | 50 | 81 | 75 | 100 | 100 |
| 84 | 5 | 80 | 24 | 70 | 21 | 67 | 25 | 90 | 100 | 100 | 100 | 100 |
| 76 | 56 | 100 | 100 | 65 | 48 | 96 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 81 | 100 | 100 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 85 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 5.--Mortality of Acarus siro on wood exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 14 days | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 15 | 90 | 15 | 15 | 40 | 60 | 85 | 100 | 100 | 100 | 100 | 100 |
| 92 | 18 | 100 | 22 | 30 | 33 | 86 | 100 | 100 | 100 | 100 | 100 | 100 |
| 84 | 10 | 85 | 44 | 70 | 63 | 87 | 85 | 100 | 100 | 100 | 100 | 100 |
| 76 | 78 | 100 | 100 | 65 | 86 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 68 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | After 35 days | | | | | | | | | | | |
| 100 | 49 | 95 | 75 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 92 | 45 | 100 | 67 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 84 | 25 | 90 | 72 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 76 | 78 | 100 | 100 | 85 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 68 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 6.--Mortality of Acarus siro on waxed cheese exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 1 day | | | | | | After 5 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 0 | 0 | 0 | 0 | 0 | 100 | 16 | 0 | 0 | 0 | 11 |
| 92 | 0 | 0 | 0 | 0 | 0 | 92 | 5 | 6 | 5 | 5 | 5 |
| 84 | 5 | 0 | 5 | 0 | 6 | 84 | 10 | 5 | 30 | 5 | 6 |
| 76 | 5 | 0 | 0 | 0 | 0 | 76 | 15 | 40 | 47 | 10 | 57 |
| 68 | 0 | 0 | 0 | 0 | 16 | 68 | 15 | 80 | 68 | 80 | 100 |
| 61 | 0 | 0 | 0 | 0 | 0 | 61 | 24 | 95 | 78 | 100 | 100 |
| 54 | 0 | 5 | 5 | 0 | 16 | 54 | 60 | 100 | 95 | 100 | 100 |
| 48 | 5 | 0 | 10 | 0 | 11 | 48 | 70 | 95 | 100 | 100 | 100 |
| 43 | 0 | 5 | 0 | 0 | 15 | 43 | 60 | 74 | 100 | 100 | 100 |
| 38 | 0 | 0 | 0 | 0 | 14 | 38 | 70 | 100 | 100 | 100 | 100 |
| 32 | 5 | 0 | 5 | 0 | 43 | 32 | 80 | 95 | 100 | 100 | 100 |
| 27 | 5 | 0 | 29 | 6 | 19 | 27 | 84 | 95 | 100 | 100 | 100 |
| 22 | 0 | 0 | 0 | 0 | 13 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 5 | 0 | 12 | 10 | 26 | 17 | 95 | 100 | 100 | 100 | 100 |
| 13 | 5 | 0 | 0 | 30 | 14 | 13 | 90 | 100 | 100 | 100 | 100 |
| 9 | 0 | 0 | 5 | 5 | 10 | 9 | 100 | 100 | 100 | 100 | 100 |
| 6 | 0 | 0 | 10 | 5 | 5 | 6 | 95 | 100 | 100 | 100 | 100 |
| | After 3 days | | | | | | After 7 days | | | | |
| 100 | 10 | 0 | 0 | 0 | 6 | 100 | 16 | 0 | 0 | 0 | 22 |
| 92 | 0 | 6 | 0 | 0 | 5 | 92 | 20 | 18 | 10 | 10 | 10 |
| 84 | 10 | 5 | 30 | 0 | 6 | 84 | 21 | 5 | 30 | 5 | 12 |
| 76 | 10 | 15 | 21 | 10 | 48 | 76 | 55 | 40 | 68 | 10 | 62 |
| 68 | 5 | 45 | 32 | 65 | 95 | 68 | 50 | 90 | 100 | 85 | 100 |
| 61 | 10 | 45 | 39 | 75 | 100 | 61 | 67 | 100 | 87 | 100 | 100 |
| 54 | 20 | 50 | 60 | 70 | 95 | 54 | 100 | 100 | 100 | 100 | 100 |
| 48 | 40 | 45 | 65 | 71 | 100 | 48 | 100 | 100 | 100 | 100 | 100 |
| 43 | 30 | 68 | 50 | 40 | 100 | 43 | 95 | 100 | 100 | 100 | 100 |
| 38 | 15 | 53 | 30 | 90 | 95 | 38 | 100 | 100 | 100 | 100 | 100 |
| 32 | 50 | 60 | 55 | 75 | 100 | 32 | 100 | 100 | 100 | 100 | 100 |
| 27 | 74 | 53 | 57 | 75 | 100 | 27 | 100 | 100 | 100 | 100 | 100 |
| 22 | 45 | 79 | 58 | 90 | 100 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 85 | 63 | 62 | 95 | 100 | 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 75 | 80 | 40 | 100 | 100 | 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | 85 | 85 | 55 | 90 | 100 | 9 | 100 | 100 | 100 | 100 | 100 |
| 6 | 55 | 65 | 71 | 100 | 100 | 6 | 100 | 100 | 100 | 100 | 100 |

TABLE 6.--Mortality of Acarus siro on waxed cheese exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 14 days | | | | | | After 35 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 53 | 15 | 15 | 10 | 89 | 100 | 84 | 69 | 65 | 100 | 100 |
| 92 | 20 | 24 | 15 | 45 | 40 | 92 | 65 | 65 | 85 | 100 | 100 |
| 84 | 58 | 20 | 55 | 35 | 62 | 84 | 90 | 95 | 100 | 100 | 100 |
| 76 | 95 | 70 | 84 | 70 | 86 | 76 | 100 | 100 | 100 | 100 | 100 |
| 68 | 100 | 100 | 100 | 95 | 100 | 68 | 100 | 100 | 100 | 100 | 100 |
| 61 | 100 | 100 | 100 | 100 | 100 | 61 | 100 | 100 | 100 | 100 | 100 |
| 54 | 100 | 100 | 100 | 100 | 100 | 54 | 100 | 100 | 100 | 100 | 100 |
| 48 | 100 | 100 | 100 | 100 | 100 | 48 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 43 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 38 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 32 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 27 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 9 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 6 | 100 | 100 | 100 | 100 | 100 |

TABLE 7.--Mortality of Acarus siro on unwaxed cheese exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 1 day | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 0 | 0 | 0 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 |
| 84 | 0 | 0 | 0 | 0 | 0 |
| 76 | 0 | 0 | 5 | 0 | 0 |
| 68 | 0 | 0 | 0 | 0 | 0 |
| 61 | 0 | 0 | 5 | 0 | 0 |
| 54 | 0 | 0 | 5 | 0 | 0 |
| 48 | 0 | 0 | 37 | 0 | 0 |
| 43 | 0 | 0 | 0 | 5 | 0 |
| 38 | 0 | 0 | 5 | 0 | 0 |
| 32 | 0 | 0 | 10 | 0 | 6 |
| 27 | 5 | 0 | 16 | 0 | 0 |
| 22 | 0 | 0 | 15 | 5 | 5 |
| 17 | 0 | 0 | 7 | 5 | 0 |
| 13 | 0 | 0 | 25 | 0 | 0 |
| 9 | 0 | 0 | 30 | 5 | 0 |
| 6 | 0 | 5 | 46 | 5 | 0 |
| | After 3 days | | | | |
| 100 | 0 | 0 | 0 | 6 | 5 |
| 92 | 5 | 0 | 0 | 0 | 0 |
| 84 | 9 | 0 | 0 | 0 | 0 |
| 76 | 0 | 0 | 5 | 10 | 5 |
| 68 | 0 | 0 | 15 | 35 | 0 |
| 61 | 10 | 0 | 45 | 5 | 5 |
| 54 | 5 | 0 | 60 | 45 | 5 |
| 48 | 6 | 0 | 58 | 66 | 24 |
| 43 | (1) | 9 | 40 | 90 | 80 |
| 38 | 20 | 5 | 50 | 70 | 70 |
| 32 | 40 | 5 | 79 | 100 | 94 |
| 27 | 0 | 0 | 68 | 80 | 100 |
| 22 | 20 | 10 | 55 | 100 | 100 |
| 17 | 20 | 15 | 73 | 93 | 100 |
| 13 | 20 | 0 | 85 | 100 | 100 |
| 9 | 0 | 15 | 100 | 100 | 100 |
| 6 | 10 | 15 | 85 | 100 | 95 |

| Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 5 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 0 | 0 | 5 | 6 | 5 |
| 92 | 5 | 0 | 0 | 0 | 5 |
| 84 | 9 | 0 | 5 | 0 | 0 |
| 76 | 0 | 0 | 5 | 10 | 10 |
| 68 | 0 | 5 | 47 | 45 | 14 |
| 61 | 25 | 10 | 85 | 10 | 24 |
| 54 | 28 | 45 | 90 | 100 | 10 |
| 48 | 13 | 38 | 100 | 100 | 38 |
| 43 | (1) | 77 | 90 | 100 | 95 |
| 38 | 30 | 79 | 100 | 100 | 100 |
| 32 | 60 | 75 | 100 | 100 | 100 |
| 27 | 27 | 74 | 100 | 100 | 100 |
| 22 | 60 | 75 | 100 | 100 | 100 |
| 17 | 87 | 70 | 100 | 100 | 100 |
| 13 | 73 | 75 | 100 | 100 | 100 |
| 9 | (1) | 100 | 100 | 100 | 100 |
| 6 | 50 | 80 | 100 | 100 | 100 |
| | After 7 days | | | | |
| 100 | 0 | 0 | 10 | 6 | 10 |
| 92 | 5 | 5 | 5 | 4 | 10 |
| 84 | 9 | 0 | 5 | 5 | 6 |
| 76 | 0 | 0 | 5 | 10 | 20 |
| 68 | 5 | 10 | 67 | 50 | 19 |
| 61 | 40 | 45 | 95 | 14 | 29 |
| 54 | 43 | 86 | 90 | 100 | 11 |
| 48 | 33 | 94 | 100 | 100 | 43 |
| 43 | (1) | 100 | 90 | 100 | 95 |
| 38 | 90 | 100 | 100 | 100 | 100 |
| 32 | 80 | 100 | 100 | 100 | 100 |
| 27 | 67 | 100 | 100 | 100 | 100 |
| 22 | 80 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | (1) | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 |

See footnote at end of table.

TABLE 7.--Mortality of Acarus siro on unwaxed cheese exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 14 days | | | | | | After 35 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 15 | 0 | 26 | 17 | ([2]) | 100 | 25 | 15 | 90 | 83 | ([3]) |
| 92 | 15 | 5 | 15 | 17 | ([2]) | 92 | 20 | 10 | 75 | 43 | ([3]) |
| 84 | 19 | 10 | 5 | 20 | 11 | 84 | 43 | 32 | 55 | 55 | ([3]) |
| 76 | 0 | 0 | 5 | 10 | 25 | 76 | 30 | 27 | 53 | 35 | ([3]) |
| 68 | 30 | 15 | 80 | 55 | 29 | 68 | 75 | 55 | 93 | 70 | 62 |
| 61 | 95 | 75 | 100 | 33 | 52 | 61 | 100 | 80 | 100 | 62 | 76 |
| 54 | 100 | 90 | 100 | 100 | 16 | 54 | 100 | 90 | 100 | 100 | 21 |
| 48 | 100 | 100 | 100 | 100 | 52 | 48 | 100 | 100 | 100 | 100 | 62 |
| 43 | ([1]) | 100 | 100 | 100 | 100 | 43 | ([1]) | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 38 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 32 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 27 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | ([1]) | 100 | 100 | 100 | 100 | 9 | ([1]) | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 6 | 100 | 100 | 100 | 100 | 100 |

[1] No data; cracks had developed in cheese in all replicates and observations were discontinued.
[2] Mites not visible because of heavy mold growth.
[3] Large colony of mites.

TABLE 8.--Mortality of Tyrophagus putrescentiae on wood exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 1 day | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 100 |
| 92 | 5 | 4 | 0 | 0 | 0 | 0 | 5 | 38 | 15 | 5 | 55 | 100 |
| 84 | 4 | 0 | 0 | 0 | 0 | 9 | 15 | 55 | 26 | 4 | 65 | 100 |
| 76 | 0 | 4 | 0 | 0 | 0 | 0 | 55 | 65 | 45 | 65 | 100 | 100 |
| 68 | 0 | 0 | 5 | 0 | 0 | 24 | 59 | 30 | 80 | 40 | 80 | 100 |
| 61 | 0 | 0 | 0 | 0 | 0 | 5 | 90 | 55 | 95 | 85 | 100 | 100 |
| 54 | 0 | 0 | 5 | 0 | 0 | 50 | 85 | 55 | 52 | 85 | 100 | 100 |
| 48 | 0 | 0 | 5 | 0 | 5 | 55 | 95 | 85 | 40 | 95 | 100 | 100 |
| 43 | 0 | 0 | 10 | 0 | 0 | 18 | 80 | 90 | 38 | 100 | 100 | 100 |
| 38 | 0 | 0 | 0 | 5 | 4 | 9 | 90 | 100 | 45 | 90 | 100 | 100 |
| 32 | 5 | 0 | 0 | 0 | 5 | 48 | 90 | 95 | 55 | 100 | 100 | 100 |
| 27 | 5 | 0 | 15 | 0 | 0 | 23 | 90 | 95 | 62 | 100 | 100 | 100 |
| 22 | 0 | 5 | 5 | 0 | 0 | 55 | 95 | 80 | 79 | 100 | 100 | 100 |
| 17 | 0 | 5 | 5 | 0 | 0 | 48 | 100 | 95 | 73 | 100 | 100 | 100 |
| 13 | 0 | 5 | 5 | 5 | 0 | 86 | 85 | 95 | 95 | 100 | 100 | 100 |
| 9 | 5 | 0 | 0 | 0 | 0 | 22 | 100 | 100 | 43 | 100 | 100 | 100 |
| 6 | 0 | 0 | 5 | 0 | 0 | 50 | 100 | 100 | 76 | 100 | 100 | 100 |
| | After 3 days | | | | | | | | | | | |
| 100 | 5 | 14 | 5 | 0 | 0 | 18 | 5 | 29 | 0 | 0 | 0 | 100 |
| 92 | 5 | 8 | 25 | 0 | 0 | 5 | 5 | 52 | 25 | 15 | 65 | 100 |
| 84 | 12 | 0 | 10 | 20 | 0 | 19 | 25 | 95 | 79 | 70 | 100 | 100 |
| 76 | 0 | 24 | 5 | 10 | 0 | 81 | 90 | 95 | 100 | 100 | 100 | 100 |
| 68 | 5 | 10 | 10 | 25 | 20 | 95 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 0 | 0 | 10 | 50 | 24 | 91 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 0 | 0 | 14 | 15 | 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 5 | 10 | 10 | 29 | 45 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 9 | 22 | 10 | 25 | 3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 0 | 5 | 5 | 55 | 54 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 5 | 28 | 5 | 40 | 43 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 9 | 0 | 20 | 42 | 68 | 91 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 5 | 35 | 10 | 40 | 50 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 0 | 20 | 20 | 58 | 75 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 14 | 40 | 30 | 60 | 48 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 5 | 26 | 20 | 40 | 37 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 9 | 20 | 20 | 40 | 37 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 8.--Mortality of Tyrophagus putrescentiae on wood exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 5 days | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 10 | 19 | 10 | 0 | 0 | 23 | 5 | 29 | 0 | 0 | 0 | 100 |
| 92 | 5 | 46 | 25 | 0 | 6 | 15 | 5 | 57 | 30 | 15 | 70 | 100 |
| 84 | 12 | 9 | 10 | 30 | 5 | 19 | 30 | 95 | 79 | 75 | 100 | 100 |
| 76 | 0 | 48 | 14 | 25 | 27 | 91 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 5 | 30 | 35 | 40 | 30 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 16 | 19 | 15 | 80 | 81 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 5 | 5 | 48 | 50 | 65 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 30 | 40 | 55 | 86 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 19 | 48 | 40 | 60 | 41 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 10 | 20 | 10 | 85 | 92 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 9 | 67 | 15 | 85 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 9 | 21 | 60 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 5 | 55 | 35 | 85 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 9 | 60 | 60 | 95 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 24 | 60 | 35 | 95 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 10 | 52 | 40 | 90 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 19 | 75 | 50 | 95 | 79 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | After 7 days | | | | | | | | | | | |
| 100 | 10 | 57 | 10 | 5 | 5 | 36 | 5 | 29 | 0 | 0 | 0 | 100 |
| 92 | 5 | 58 | 25 | 0 | 6 | 25 | 5 | 57 | 35 | 25 | 70 | 100 |
| 84 | 12 | 19 | 10 | 30 | 10 | 24 | 30 | 95 | 84 | 75 | 100 | 100 |
| 76 | 0 | 67 | 33 | 25 | 27 | 91 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 5 | 75 | 60 | 60 | 40 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 26 | 40 | 40 | 80 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 5 | 30 | 57 | 95 | 74 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 60 | 60 | 65 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 33 | 83 | 45 | 80 | 68 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 25 | 40 | 30 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 43 | 86 | 40 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 9 | 70 | 80 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 7 | 75 | 40 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 10 | 85 | 75 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 0 | 75 | 55 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 25 | 78 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 38 | 85 | 60 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 8.--Mortality of Tyrophagus putrescentiae on wood exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. |
| | After 14 days | | | | | | | | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 25 | 71 | 10 | 5 | 25 | 50 | 15 | 48 | 43 | 67 | 75 | 100 |
| 92 | 9 | 92 | 30 | 5 | 17 | 55 | 5 | 71 | 65 | 50 | 85 | 100 |
| 84 | 12 | 48 | 15 | 30 | 15 | 33 | 50 | 90 | 95 | 85 | 100 | 100 |
| 76 | 10 | 95 | 76 | 30 | 55 | 100 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 24 | 95 | 95 | 65 | 40 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 63 | 85 | 95 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 62 | 95 | 95 | 100 | 87 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 90 | 95 | 90 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 95 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 90 | 90 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 95 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 75 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | After 35 days | | | | | | | | | | | |
| 100 | 30 | 86 | 40 | 14 | 100 | 95 | 90 | 100 | 100 | 100 | 100 | 100 |
| 92 | 9 | 96 | 40 | 14 | 55 | 75 | 85 | 100 | 100 | 100 | 100 | 100 |
| 84 | 12 | 67 | 35 | 50 | 70 | 57 | 95 | 100 | 100 | 100 | 100 | 100 |
| 76 | 20 | 100 | 86 | 35 | 100 | 100 | 95 | 100 | 100 | 100 | 100 | 100 |
| 68 | 81 | 100 | 100 | 80 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 61 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 54 | 100 | 100 | 100 | 100 | 91 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 48 | 100 | 100 | 100 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 9.--Mortality of Tyrophagus putrescentiae on waxed cheese exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 1 day | | | | | | After 5 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 6 | 0 | 0 | 0 | 0 | 100 | 11 | 0 | 6 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 | 92 | 5 | 0 | 0 | 10 | 0 |
| 84 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 30 | 0 | 5 |
| 76 | 0 | 0 | 0 | 0 | 0 | 76 | 19 | 21 | 15 | 0 | 5 |
| 68 | 0 | 0 | 0 | 0 | 0 | 68 | 10 | 15 | 9 | 10 | 50 |
| 61 | 0 | 0 | 0 | 0 | 6 | 61 | 20 | 37 | 10 | 40 | 94 |
| 54 | 10 | 0 | 0 | 0 | 5 | 54 | 50 | 58 | 45 | 20 | 65 |
| 48 | 10 | 0 | 0 | 0 | 0 | 48 | 76 | 68 | 37 | 20 | 76 |
| 43 | 0 | 0 | 0 | 0 | 5 | 43 | 45 | 90 | 25 | 15 | 80 |
| 38 | 0 | 0 | 0 | 0 | 23 | 38 | 45 | 78 | 70 | 40 | 92 |
| 32 | 5 | 0 | 0 | 5 | 0 | 32 | 75 | 90 | 63 | 52 | 65 |
| 27 | 5 | 0 | 5 | 0 | 5 | 27 | 47 | 95 | 85 | 47 | 57 |
| 22 | 0 | 0 | 5 | 0 | 4 | 22 | 55 | 90 | 71 | 20 | 78 |
| 17 | 11 | 0 | 0 | 0 | 0 | 17 | 50 | 82 | 87 | 48 | 90 |
| 13 | 0 | 0 | 0 | 0 | 13 | 13 | 71 | 100 | 85 | 53 | 100 |
| 9 | 0 | 0 | 10 | 0 | 0 | 9 | 60 | 100 | 80 | 79 | 86 |
| 6 | 10 | 0 | 0 | 0 | 0 | 6 | 53 | 100 | 90 | 71 | 80 |
| | After 3 days | | | | | | After 7 days | | | | |
| 100 | 6 | 0 | 0 | 0 | 0 | 100 | 17 | 5 | 12 | 0 | 12 |
| 92 | 5 | 0 | 0 | 10 | 0 | 92 | 5 | 0 | 0 | 15 | 0 |
| 84 | 0 | 0 | 10 | 0 | 5 | 84 | 0 | 0 | 50 | 0 | 5 |
| 76 | 5 | 12 | 10 | 0 | 0 | 76 | 24 | 33 | 30 | 0 | 15 |
| 68 | 0 | 0 | 5 | 5 | 10 | 68 | 35 | 50 | 18 | 25 | 70 |
| 61 | 10 | 5 | 5 | 15 | 12 | 61 | 55 | 90 | 42 | 55 | 100 |
| 54 | 30 | 8 | 15 | 5 | 10 | 54 | 80 | 100 | 65 | 80 | 85 |
| 48 | 43 | 9 | 21 | 0 | 48 | 48 | 95 | 100 | 58 | 65 | 95 |
| 43 | 20 | 25 | 5 | 0 | 15 | 43 | 90 | 100 | 75 | 80 | 100 |
| 38 | 10 | 39 | 35 | 0 | 54 | 38 | 90 | 100 | 90 | 100 | 100 |
| 32 | 35 | 21 | 21 | 5 | 35 | 32 | 90 | 100 | 95 | 90 | 90 |
| 27 | 26 | 40 | 30 | 0 | 24 | 27 | 90 | 100 | 90 | 100 | 100 |
| 22 | 14 | 38 | 29 | 0 | 43 | 22 | 86 | 100 | 100 | 95 | 100 |
| 17 | 22 | 15 | 22 | 5 | 45 | 17 | 89 | 100 | 96 | 100 | 95 |
| 13 | 24 | 40 | 27 | 16 | 52 | 13 | 100 | 100 | 96 | 90 | 100 |
| 9 | 15 | 40 | 45 | 7 | 29 | 9 | 100 | 100 | 90 | 100 | 100 |
| 6 | 21 | 50 | 20 | 19 | 40 | 6 | 90 | 100 | 100 | 95 | 100 |

TABLE 9.--Mortality of Tyrophagus putrescentiae on waxed cheese exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 14 days | | | | | | After 35 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 28 | 5 | 35 | 15 | 59 | 100 | 72 | 30 | 88 | 100 | 100 |
| 92 | 5 | 0 | 10 | 20 | 50 | 92 | 45 | 35 | 100 | 100 | 89 |
| 84 | 5 | 19 | 50 | 0 | 35 | 84 | 40 | 90 | 90 | 95 | 95 |
| 76 | 62 | 83 | 45 | 10 | 50 | 76 | 69 | 100 | 95 | 100 | 100 |
| 68 | 95 | 95 | 45 | 55 | 90 | 68 | 100 | 100 | 64 | 100 | 95 |
| 61 | 100 | 100 | 74 | 75 | 100 | 61 | 100 | 100 | 100 | 100 | 100 |
| 54 | 100 | 100 | 95 | 100 | 100 | 54 | 100 | 100 | 100 | 100 | 100 |
| 48 | 100 | 100 | 100 | 90 | 100 | 48 | 100 | 100 | 100 | 100 | 100 |
| 43 | 100 | 100 | 100 | 100 | 100 | 43 | 100 | 100 | 100 | 100 | 100 |
| 38 | 100 | 100 | 100 | 100 | 100 | 38 | 100 | 100 | 100 | 100 | 100 |
| 32 | 100 | 100 | 100 | 100 | 100 | 32 | 100 | 100 | 100 | 100 | 100 |
| 27 | 100 | 100 | 100 | 100 | 100 | 27 | 100 | 100 | 100 | 100 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 9 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 6 | 100 | 100 | 100 | 100 | 100 |

TABLE 10.--Mortality of Tyrophagus putrescentiae on unwaxed cheese exposed to various combinations of temperature and relative humidity

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 1 day | | | | | | After 5 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 5 | 0 | 0 | 0 | 0 | 100 | 5 | 0 | 0 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 | 92 | 0 | 0 | 0 | 0 | 0 |
| 84 | 0 | 0 | 5 | 0 | 6 | 84 | 0 | 0 | 5 | 0 | 11 |
| 76 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 0 | 0 |
| 68 | 5 | 0 | 0 | 0 | 0 | 68 | 5 | 5 | 7 | 0 | 0 |
| 61 | 5 | 0 | 0 | 0 | 0 | 61 | 9 | 15 | 25 | 0 | 6 |
| 54 | 0 | 5 | 0 | 0 | 5 | 54 | 0 | 5 | 24 | 10 | 5 |
| 48 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 5 | 45 | 27 | 5 |
| 43 | 0 | 0 | 0 | 0 | 0 | 43 | 9 | 20 | 70 | 47 | 5 |
| 38 | 5 | 0 | 0 | 0 | 0 | 38 | 13 | 0 | 47 | 45 | 5 |
| 32 | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 4 | 53 | 50 | 0 |
| 27 | 0 | 0 | 5 | 0 | 0 | 27 | 9 | 4 | 85 | 50 | 12 |
| 22 | 0 | 0 | 0 | 0 | 5 | 22 | 7 | 0 | 67 | 92 | 23 |
| 17 | 5 | 0 | 0 | 0 | 0 | 17 | 5 | 0 | 100 | 29 | 9 |
| 13 | 0 | 0 | 0 | 5 | 0 | 13 | 0 | 0 | 100 | 95 | 10 |
| 9 | 0 | 0 | 0 | 0 | 0 | 9 | (1) | 6 | 100 | 85 | 12 |
| 6 | 0 | 5 | 0 | 0 | 0 | 6 | 0 | 24 | 100 | 75 | 18 |
| | After 3 days | | | | | | After 7 days | | | | |
| 100 | 5 | 0 | 0 | 0 | 0 | 100 | 5 | 0 | 0 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 | 92 | 0 | 0 | 0 | 10 | 4 |
| 84 | 0 | 0 | 5 | 0 | 11 | 84 | 0 | 0 | 5 | 0 | 11 |
| 76 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 0 | 5 | 0 | 0 |
| 68 | 5 | 0 | 0 | 0 | 0 | 68 | 5 | 5 | 7 | 0 | 0 |
| 61 | 5 | 0 | 5 | 0 | 0 | 61 | 9 | 25 | 40 | 5 | 6 |
| 54 | 0 | 5 | 0 | 0 | 5 | 54 | 4 | 5 | 62 | 30 | 5 |
| 48 | 0 | 5 | 0 | 0 | 5 | 48 | (1) | 5 | 90 | 50 | 5 |
| 43 | 9 | 0 | 20 | 18 | 0 | 43 | 20 | 35 | 70 | 88 | 5 |
| 38 | 7 | 0 | 7 | 15 | 0 | 38 | 13 | 33 | 100 | 70 | 15 |
| 32 | 0 | 0 | 20 | 10 | 0 | 32 | 0 | 18 | 93 | 65 | 23 |
| 27 | 6 | 0 | 15 | 10 | 0 | 27 | 18 | 17 | 100 | 90 | 12 |
| 22 | 0 | 0 | 0 | 17 | 14 | 22 | 5 | 5 | 100 | 100 | 45 |
| 17 | 5 | 0 | 20 | 0 | 4 | 17 | 10 | 38 | 100 | 64 | 17 |
| 13 | 0 | 0 | 40 | 67 | 5 | 13 | 0 | 33 | 100 | 100 | 10 |
| 9 | 0 | 4 | 43 | 40 | 31 | 9 | (1) | 25 | 100 | 95 | 48 |
| 6 | 0 | 14 | 25 | 45 | 0 | 6 | 20 | 57 | 100 | 95 | 53 |

See footnote at end of table.

TABLE 10.--Mortality of Tyrophagus putrescentiae on unwaxed cheese exposed to various combinations of temperature and relative humidity--Continued

| Relative humidity | Mortality at temperature of-- | | | | | Relative humidity | Mortality at temperature of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| | After 14 days | | | | | | After 35 days | | | | |
| Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 100 | 5 | 0 | 0 | 5 | ([2]) | 100 | 5 | 5 | 45 | 20 | ([3]) |
| 92 | 0 | 5 | 0 | 10 | ([2]) | 92 | 15 | 5 | 30 | 29 | ([3]) |
| 84 | 5 | 5 | 5 | 0 | 17 | 84 | 9 | 9 | 14 | 53 | ([3]) |
| 76 | 10 | 0 | 7 | 5 | 0 | 76 | 10 | 0 | 20 | 70 | ([3]) |
| 68 | 6 | 14 | 13 | 0 | 0 | 68 | 13 | 19 | 53 | 75 | 68 |
| 61 | 9 | 60 | 85 | 10 | 6 | 61 | 9 | 70 | 100 | 47 | 17 |
| 54 | 5 | 29 | 100 | 80 | 14 | 54 | 35 | 71 | 100 | 85 | 23 |
| 48 | ([1]) | 69 | 100 | 95 | 5 | 48 | ([1]) | 100 | 100 | 95 | 5 |
| 43 | 20 | 60 | 100 | 100 | 35 | 43 | 100 | 100 | 100 | 100 | 80 |
| 38 | 26 | 76 | 100 | 100 | 35 | 38 | 100 | 100 | 100 | 100 | 90 |
| 32 | 16 | 73 | 100 | 100 | 86 | 32 | 100 | 100 | 100 | 100 | 100 |
| 27 | 50 | 74 | 100 | 100 | 94 | 27 | 100 | 100 | 100 | 100 | 100 |
| 22 | 20 | 67 | 100 | 100 | 100 | 22 | 100 | 100 | 100 | 100 | 100 |
| 17 | 21 | 43 | 100 | 100 | 100 | 17 | 100 | 100 | 100 | 100 | 100 |
| 13 | 33 | 67 | 100 | 100 | 100 | 13 | 100 | 100 | 100 | 100 | 100 |
| 9 | ([1]) | 65 | 100 | 100 | 100 | 9 | ([1]) | 100 | 100 | 100 | 100 |
| 6 | 40 | 95 | 100 | 100 | 94 | 6 | 100 | 100 | 100 | 100 | 100 |

[1] No data; cracks had developed in cheese in all replicates, and observations were discontinued.
[2] Mites not visible because of heavy mold growth.
[3] Large colony of mites.

TABLE 11.--Number of days required to produce 100-percent mortality of Acarus siro and Tyrophagus putrescentiae on various surfaces exposed to different combinations of temperature and relative humidity

| Relative humidity | Days to produce 100-percent mortality | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | On wood at temperature of-- | | | | | | | | | | | | On waxed cheese at temperature of-- | | | | | On cheese at temperature of-- | | | | |
| | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 62°F. | 68°F. | 74°F. | 80°F. | 86°F. | 92°F. | 98°F. | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. | 32°F. | 38°F. | 44°F. | 50°F. | 56°F. |
| **Acarus siro** | | | | | | | | | | | | | | | | | | | | | | |
| | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days | Days |
| 100 | (1) | (1) | (1) | (1) | 28 | 28 | 28 | 12 | 12 | 10 | 3 | 1 | (1) | (1) | (1) | 28 | 21 | (1) | (1) | (1) | (1) | (1) |
| 92 | (1) | 7 | (1) | 28 | 28 | 21 | 14 | 12 | 11 | 14 | 2 | 1 | (1) | (1) | (1) | 28 | 28 | (1) | (1) | (1) | (1) | (1) |
| 84 | (1) | (1) | (1) | (1) | 28 | 28 | 21 | 10 | 6 | 1 | 1 | 1 | (1) | (1) | (1) | 35 | 28 | (1) | (1) | (1) | (1) | (1) |
| 76 | (1) | 6 | 4 | (1) | 28 | 9 | 10 | 1 | 2 | 1 | 1 | 1 | 21 | 21 | 28 | 28 | 14 | (1) | (1) | (1) | (1) | (1) |
| 68 | 11 | 6 | 4 | 3 | 14 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 11 | 14 | 6 | 21 | 4 | (1) | (1) | (1) | (1) | (1) |
| 61 | 9 | 6 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 6 | 10 | 4 | 3 | 35 | (1) | 9 | (1) | (1) |
| 54 | 9 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 5 | 6 | 5 | 4 | 14 | (1) | 8 | 5 | (1) |
| 48 | 8 | 5 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 6 | 5 | 4 | 3 | 10 | 8 | 4 | 5 | (1) |
| 43 | 6 | 5 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 6 | 5 | 5 | 3 | (1) | 7 | 8 | 4 | 14 |
| 38 | 6 | 5 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 5 | 5 | 4 | 4 | 9 | 7 | 4 | 4 | 5 |
| 32 | 6 | 5 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 6 | 5 | 4 | 3 | 9 | 7 | 5 | 3 | 4 |
| 27 | 6 | 4 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 6 | 5 | 4 | 3 | 11 | 7 | 5 | 5 | 3 |
| 22 | 6 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 4 | 2 | 9 | 6 | 5 | 3 | 3 |
| 17 | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 5 | 5 | 4 | 3 | 7 | 6 | 4 | 4 | 3 |
| 13 | 5 | 5 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 4 | 5 | 3 | 2 | 7 | 6 | 5 | 3 | 3 |
| 9 | 5 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 5 | 4 | 3 | (1) | 7 | 3 | 3 | 3 |
| 6 | 5 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 5 | 5 | 3 | 2 | 7 | 6 | 5 | 3 | 4 |
| **Tyrophagus putrescentiae** | | | | | | | | | | | | | | | | | | | | | | |
| 100 | (1) | (1) | (1) | (1) | 35 | (1) | (1) | 35 | 35 | 21 | 21 | 1 | (1) | (1) | (1) | 35 | 28 | (1) | (1) | (1) | (1) | (1) |
| 92 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | 35 | 28 | 28 | 21 | 1 | (1) | (1) | 35 | 35 | (1) | (1) | (1) | (1) | (1) | (1) |
| 84 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | 28 | 21 | 21 | 3 | 1 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| 76 | (1) | 28 | (1) | (1) | 35 | 8 | (1) | 4 | 3 | 3 | 1 | 1 | (1) | 21 | (1) | 35 | 28 | (1) | (1) | (1) | (1) | (1) |
| 68 | (1) | 21 | 21 | (1) | (1) | 4 | 2 | 2 | 2 | 3 | 2 | 1 | 21 | 21 | (1) | 35 | (1) | (1) | (1) | (1) | (1) | (1) |
| 61 | 28 | 21 | 21 | 28 | 8 | 4 | 2 | 2 | 2 | 2 | 1 | 1 | 14 | 11 | 21 | 28 | 6 | (1) | (1) | 21 | (1) | (1) |
| 54 | 21 | 21 | 21 | 8 | (1) | 2 | 2 | 3 | 3 | 2 | 1 | 1 | 10 | 7 | 21 | 11 | 11 | (1) | (1) | 14 | (1) | (1) |
| 48 | 21 | 21 | 21 | 6 | (1) | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 8 | 7 | 12 | 35 | 8 | (1) | 35 | 9 | (1) | (1) |
| 43 | 21 | 14 | 21 | 9 | 9 | 3 | 2 | 2 | 3 | 1 | 1 | 1 | 10 | 6 | 11 | 9 | 7 | 28 | 35 | 9 | 8 | (1) |
| 38 | 21 | 21 | 21 | 6 | 6 | 3 | 2 | 1 | 3 | 2 | 1 | 1 | 10 | 6 | 14 | 7 | 6 | 28 | 35 | 7 | 10 | (1) |
| 32 | 21 | 14 | 21 | 7 | 5 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 9 | 6 | 10 | 8 | 8 | 28 | 35 | 8 | 10 | 21 |
| 27 | 21 | 14 | 11 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 9 | 6 | 10 | 7 | 7 | 28 | 35 | 7 | 8 | 21 |
| 22 | 21 | 14 | 14 | 6 | 6 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 8 | 6 | 7 | 8 | 6 | 28 | 35 | 6 | 6 | 14 |
| 17 | 21 | 14 | 10 | 6 | 7 | 3 | 1 | 2 | 2 | 1 | 1 | 1 | 8 | 6 | 9 | 7 | 8 | 28 | 35 | 5 | 11 | 14 |
| 13 | 21 | 14 | 14 | 6 | 6 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 6 | 5 | 11 | 8 | 5 | 28 | 28 | 5 | 6 | 14 |
| 9 | 21 | 14 | 14 | 6 | 6 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 7 | 5 | 10 | 6 | 7 | (1) | 35 | 5 | 8 | 11 |
| 6 | 14 | 14 | 12 | 6 | 7 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 10 | 5 | 6 | 8 | 6 | 14 | 14 | 12 | 6 | 7 |

[1] Mites still living at the end of 35 days.

TABLE 12.--Cumulative percentages[1] of Acarus siro and Tyrophagus putrescentiae eggs hatched at various combinations of temperature and relative humidity

| Days | Percentage of eggs hatched | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acarus siro | | | | | | | | | | | | | | | | | Tyrophagus putrescentiae | | | | | | | | | | |
| | 56° F. and r.h. of-- | | | | | | 50° F. and r.h. of-- | | | | | | 44° F. and r.h. of-- | | | | 38° F. & r.h. of- | 56° F. and r.h. of-- | | | | | | 50° F. and r.h. of-- | | | | | |
| | 100 | 92 | 84 | 76 | 68 | 61 | 100 | 92 | 84 | 76 | 68 | 61 | 100 | 92 | 84 | 76 | 100 | 100 | 92 | 84 | 76 | 68 | 61 | 100 | 92 | 84 | 76 | 68 | 61 |
| Number | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| 10 | 13 | 15 | 3 | 3 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11 | 33 | 35 | 13 | 15 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12 | 35 | 45 | 15 | 25 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 13 | 45 | 45 | 18 | 25 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 14 | 50 | 58 | 35 | 38 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5 | 18 | --- | --- | --- | --- | --- | --- | --- | --- |
| 15 | 55 | 60 | 55 | 40 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 15 | 18 | 10 | 55 | --- | --- | --- | --- | --- | --- | --- | --- |
| 16 | 60 | --- | --- | 53 | --- | 3 | 10 | 15 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 45 | 48 | 45 | 63 | 5 | 3 | --- | --- | --- | --- | --- | --- |
| 17 | --- | --- | --- | --- | 20 | 8 | 20 | 38 | 27 | --- | --- | --- | --- | --- | --- | --- | --- | 48 | 55 | 63 | 65 | 30 | 28 | --- | --- | --- | --- | --- | --- |
| 18 | --- | --- | --- | --- | --- | 13 | 45 | 43 | 47 | 13 | --- | --- | --- | --- | --- | --- | --- | 53 | --- | 63 | 65 | 35 | 33 | --- | --- | --- | --- | --- | --- |
| 19 | --- | --- | --- | --- | --- | 23 | 58 | 68 | 73 | 30 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 70 | 70 | 38 | 38 | --- | --- | --- | --- | --- | --- |
| 20 | --- | --- | --- | --- | --- | 30 | 63 | 75 | 77 | 48 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 78 | 75 | 48 | 58 | --- | --- | --- | --- | --- | --- |
| 21 | --- | --- | --- | --- | --- | --- | 75 | 78 | 80 | 55 | 15 | 8 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 50 | --- | --- | --- | --- | --- | --- | --- |
| 22 | --- | --- | --- | --- | --- | --- | 80 | 85 | 87 | 65 | 20 | 25 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 23 | --- | --- | --- | --- | --- | --- | 80 | 85 | 90 | 75 | 30 | 38 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24 | --- | --- | --- | --- | --- | --- | 83 | 85 | --- | 75 | 30 | 38 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 25 | --- | --- | --- | --- | --- | --- | --- | 88 | --- | 83 | 33 | 43 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 26 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 27 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 28 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 13 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 29 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 18 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 30 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 23 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5 | 13 | 25 | --- | --- | --- |
| 31 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 28 | 13 | 3 | --- | --- | --- | --- | --- | --- | --- | --- | 18 | 20 | 38 | 5 | 17 | 23 |
| 32 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 33 | 18 | 15 | --- | --- | --- | --- | --- | --- | --- | --- | 25 | 23 | 53 | 10 | 33 | 40 |
| 33 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 35 | 20 | 15 | --- | --- | --- | --- | --- | --- | --- | --- | 35 | 30 | 55 | 20 | 43 | 45 |
| 34 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 35 | 30 | 30 | --- | --- | --- | --- | --- | --- | --- | --- | 43 | 40 | 65 | 30 | 45 | 48 |
| 35 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 38 | 33 | 30 | 5 | --- | --- | --- | --- | --- | --- | --- | 48 | 48 | 68 | 45 | 48 | 53 |
| 36 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 43 | 38 | 35 | 8 | --- | --- | --- | --- | --- | --- | --- | 53 | 53 | 75 | 58 | 53 | 58 |
| 37 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 45 | 40 | 40 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 58 | --- |
| 38 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 45 | 43 | 43 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 48 | 45 | 45 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 40 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 41 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 42 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 43 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 44 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 45 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 46 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 47 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 48 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 8 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 49 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 8 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 50 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 8 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 51 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 8 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 52 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 10 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 53 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 13 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 54 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 18 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Add days correction factor[2] | 0 | 0 | 0.1 | 0.1 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.9 | 1.0 | 1.0 | 1.1 | 1.9 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.5 | 0.5 | 0.4 | 0.6 | 0.5 | 0.5 |

[1] All percentages above the figures given are 0; all percentages below the figures are repetitions of the last figure given.

[2] These figures are to compensate for the fact that the eggs were laid at 56° F. and r.h. of 92 percent over a period of 24 hours, and thus were incubated at that temperature and relative humidity for part of their first day.

TABLE 13.--Weight of waxed miniature cheddars and extent of mite infestation after exposure to large populations of Acarus siro and Tyrophagus putrescentiae at 56° F. and various relative humidities

| Relative humidity and condition of cheese | Weight of cheese | | | Extent of mite infestation |
|---|---|---|---|---|
| | At start of test | After 4 weeks | Gain or loss during test | |
| | Grams | Grams | Percent | |
| 100 percent r.h.: | | | | |
| Boxed cheese..... | 471.1 | 471.9 | +0.17 | 1,000 or more mites over entire cheese. |
| Unboxed cheese..... | 471.3 | 472.1 | +.17 | 1,000 or more mites over entire cheese. |
| 92 percent r.h.: | | | | |
| Boxed cheese..... | 483.1 | 482.0 | -.23 | 1,000 or more mites over entire cheese. |
| Unboxed cheese..... | 472.9 | 471.8 | -.23 | 1,000 or more mites over entire cheese. |
| 84 percent r.h.: | | | | |
| Boxed cheese..... | 463.0 | 462.3 | -.15 | 1,000 or more mites over entire cheese. |
| Unboxed cheese..... | 472.3 | 471.5 | -.17 | 1,000 or more mites over entire cheese. |
| 76 percent r.h.: | | | | |
| Boxed cheese..... | 463.5 | 462.1 | -.30 | About 200 mites over entire cheese. |
| Unboxed cheese..... | 492.1 | 491.2 | -.18 | About 200 mites over entire cheese. |
| 68 percent r.h.: | | | | |
| Boxed cheese..... | 470.0 | 469.1 | -.19 | About 10 T. putrescentiae mostly along edges of cheese. |
| Unboxed cheese..... | 478.6 | 476.5 | -.44 | About 100 mites mostly along edges of cheese. |
| 61 percent r.h.: | | | | |
| Boxed cheese..... | 474.4 | 473.4 | -.21 | No live mites. |
| Unboxed cheese..... | 464.3 | 462.5 | -.39 | About 200 mites in crack along edge of cheese. |
| 54 percent r.h.: | | | | |
| Boxed cheese..... | 464.4 | 462.7 | -.37 | No live mites. |
| Unboxed cheese..... | 475.0 | 473.1 | -.40 | About 10 T. putrescentiae in crack on edge of cheese. |
| 48 percent r.h.: | | | | |
| Boxed cheese..... | 464.4 | 462.3 | -.45 | About 20 T. putrescentiae in crack on edge of cheese. |
| Unboxed cheese..... | 470.3 | 468.6 | -.36 | No live mites. |
| 43 percent r.h.: | | | | |
| Boxed cheese..... | 457.8 | 455.7 | -.46 | No live mites. |
| Unboxed cheese..... | 472.8 | 472.0 | -.17 | No live mites. |
| 38 percent r.h.: | | | | |
| Boxed cheese..... | 469.1 | 467.7 | -.30 | No live mites. |
| Unboxed cheese..... | 489.3 | 487.4 | -.39 | 3 T. putrescentiae in a crack in the cheese. |

## Review of Literature

Observations on the life history of mites have been made by many workers in this field. Most of these studies include some data on temperature and humidity. Various species names have been used, but to avoid confusion, the names used by Nesbitt (18), Baker and Wharton (1), and Robertson (30) will be used for the various mite species.

Almost all of the cheese mites belong to the Glycyphagidae, Carpoglyphidae, or Acaridae families. According to Ewing and Nesbitt (7), Acaridae is the correct name for the family formerly known as Tyroglyphidae.

The presently accepted names of some of the common cheese mites and their synonyms are as follows:

| Presently accepted name | Synonyms |
|---|---|
| Acarus siro L. 1758 | Tyroglyphus farinae |
| | Aleurobius farinae |
| Tyrophagus putrescentiae (Schr., 1781) | Tyrophagus castellanii |
| | T. longior var. castellanii |
| | T. nadinus |
| | T. noxius |
| Tyrophagus longior (Gervais, 1884) | T. dimidiatus |
| | T. infestans |
| Lepidoglyphus destructor Schr. 1781 | Glycyphagus destructor |
| | G. cadaverus[5] |
| | Acarus destructor |
| Carpoglyphus lactis L. 1758 | A. lactis |
| | Carpoglyphus passulorum |
| | C. anonymous |
| Caloglyphus rodionovi Zakhv. 1937 | Tyroglyphus mycophagus |
| Glycyphagus domesticus DeGeer 1778 | No synonyms. |

The life cycle of the mites in the cheese mite group, as we understand it today, was summarized by Michael in 1884 (17). When the egg hatched, a six-legged larva appeared. This larva fed for a time and then entered an inert, brief resting stage. After ecdysis, an octopod, the protonymph, appeared. After feeding and growth, the protonymph also went into a resting stage. Upon ecdysis, either a deutonymph or a specialized form called the hypopus appeared. The hypopus stage will be discussed separately later. The deutonymph very closely resembled the protonymph, but was larger. The deutonymph fed and grew and finally entered into a resting stage. Ecdysis produced the adult mite.

Reuter (25) described three nymphal stages, the protonymph, the deutonymph, and the tritonymph. Reuter's deutonymph, an active migratory form corresponding to Michael's hypopus, was omitted in many life cycles. The tritonymph of Reuter was the same as the deutonymph described by Michael.

[5] Glycyphagus cadaverus is a distinct species in Russia.

Eales (6) reported on the life histories of certain cheese mites. These studies lacked temperature and relative humidity data, and the time spent in each stage of development was not definitely ascertained.

Newstead and Duvall (19) published some biological observations on A. siro and L. destructor. A. siro females at 64° to 71° F. each laid 3 to 4 eggs per day and a total of 20 to 30 eggs during their lifetime. A typical life history at this temperature was as follows: Egg 3 to 4 days, larva 3 days, resting larva 1 to 2 days, and nymphal stages 6 to 8 days. The life history of L. destructor was almost identical to that of A. siro. A moisture content of at least 13 percent (r. h. of about 58 percent) was necessary for the survival of these mites in grain or flour. At temperatures of 60° to 70° F., the mite populations increased very rapidly, while at 40° to 50° F., they increased slowly. Newstead and Morris (20) found that when the moisture content in flour was maintained at 13 percent, the population of A. siro multiplied rapidly, but when the moisture content was 12.4 percent, it increased very slowly. When the moisture content was 12.2 percent, all mites were dead in 2 to 3 weeks.

Belyaev et al. (2) stated that A. siro and T. longior developed best in grain at 64.4° to 71.6° F. and 18 to 24 percent moisture content. At this temperature and humidity, the eggs hatched in 4 to 5 days, but at 46.4° to 50° F., 11 to 12 days were required.

Smaragdova (36) found that grain mites reared at 86° F. were more resistant to heat and cold than were mites reared at 68° F. In these tests, a dry atmosphere increased the rate of mortality. In 1935, Sokolov (42) reported A. siro to be the most prevalent mite in stored grain. A moisture content of 16 to 20 percent and a temperature of 64.4° to 77° F. were optimum for development, but movement, mating, oviposition, and hatching occurred at temperatures as low as 35.6° F.

Observations of Zakhvatkin (46) that mites were not present in hay or straw unless the moisture content was above 12 percent substantiate the findings of Newstead and Morris (20).

Dustan (5) reported on the results of some experiments with A. siro on cheese. At 60° F. the eggs of this mite hatched in 12 to 14 days, and 3 to 4 weeks were required for development to the adult stage. No humidity data were mentioned. Practically no mite damage was observed in cheese stored at 32° to 35° F. Even at 35° to 40° F., cheese could be stored for several months with comparative safety, but at temperatures above 40° F. the mites were quite active and caused noticeable damage. At temperatures of 50° to 60° F., the mites were very active, and the damage to the cheese was quite extensive. High humidity favored the development of mites, but not to so great an extent as high temperature. The last of 50 A. siro became dormant at 26.9° F. and the first became active again at 28.7° F. The largest individuals reacted first. At 37° to 40° F., the mites continued to feed and probably breed at a very slow rate.

Rodionov (31) placed mites of various species in a glass tube with a temperature gradient to determine what temperature was most preferred by different species of mites. The temperature at which most mites congregated was as follows: A. siro 67° F.; L. destructor 73.4° F.; T. putrescentiae 76.1° F.; and C. rodionovi 93.2° F.

Oboussier (21) tested the effect of humidity on C. lactis, G. domesticus, G. cadaverus, and T. putrescentiae. The development of all forms was favored by moisture. T. putrescentiae bred rapidly at 98 percent r. h., were less active at 75 percent, and were mostly dead after 24 hours at 54 percent. Oboussier also observed that infestation of new material was due mostly to wandering nymphs. The development time varied a great deal among individuals.

Kozulina (15) exposed eggs of A. siro and T. putrescentiae to r. h. of 30 to 100 percent and temperatures of 68° to 71.6° F. The largest percentage of eggs of A. siro hatched at 100 percent r. h. The lowest humidity at which any eggs hatched was 60 percent. The largest percentage of eggs of T. putrescentiae hatched at 70 percent, and 55 percent was the lowest r. h. at which eggs of this species hatched. A temperature of 32° F. for 24 hours killed 70 to 92.5 percent of the 3- to 4-day-old eggs of A. siro. Polezhaev (24) found the optimum conditions for the development of A. siro to be a temperature of 62.6° to 77° F. and a r. h. of 60 to 100 percent.

Gilyarov (8) noted that A. siro and T. putrescentiae fed on mold growing on seeds of kok-saghuiz. The mites could not penetrate the hard seed coat, but their feeding on the mold prevented lumping of the seed and increased its germination. A colony of mites could clean mold-covered seed in 3 to 4 days.

Zakhvatkin (47) stated that the lowest r. h. at which A. siro survived was 60 percent, and the optimum was 75 to 80. The lowest r. h. at which T. putrescentiae survived was 70 and the optimum 90 percent. Temperature affected mites less than humidity did. A. siro did not develop at temperatures below 46.4° F. nor T. putrescentiae below 48.2° F. The best temperatures for development were 68° F. to 71. 6° F. for A. siro and 77° F. for T. putrescentiae.

Hughes (11) showed that at 68° F., a r. h. higher than 58. 3 to 65 percent was essential for the survival of A. siro. At 80 and 90 percent r. h., breeding began in 5 days, but at 74 percent r. h., breeding did not begin until after 9 days. All mites were dead in 1 day at 20 percent r. h., in 2 days at 45. 5 percent, and in 4 days at 58. 3 percent. After 9 days at a r. h. of 65. 6 percent, mites were still living but not breeding.

Studying T. putrescentiae on dried fruit, Lombardini (16) found that this mite developed most rapidly at 77° F. It spent 7 days in the egg stage, 5 days as a larva, 3 days as a protonymph, and 2 days as a deutonymph. At 42. 8° F., eggs hatched after 13 days, but at 89. 6° F., no eggs hatched at all. Humidity was reported to have no apparent effect on the hatching time.

Solomon (37, 38, and 39) reported that humidity played a dominant role in the life of A. siro. An increase in relative humidity increased the rate of multiplication. These mites were unable to live in grain or flour with a moisture content of less than 12 percent (55 to 60 percent r. h.). The optimum temperature for growth and survival was 64. 4° to 77° F. Temperatures of 104° F. caused complete mortality, but the mites were very resistant to low temperatures. Like A. siro, mites of the genus Glycyphagus were unable to live in grain or flour with less than 12-percent moisture content. Mites of the genus Acarus did best in media with a moisture content of more than 14 percent, while Glycyphagus preferred a moisture content of 13 to 16 percent.

Robertson (27) showed that different species of mites were prevalent in cheese stored at different temperatures. T. longior and Tyrolichus casei were most prevalent at curing room temperatures. At 40° to 50° F., Tyrophagus was rare, and A. siro, G. domesticus, and L. destructor were common. In another article (28), she reports that cheese mite adults can live at least 7 months at 50° F.

Gray (9) reported A. siro as the most important mite pest of grain. A moisture content of 14 percent was necessary for infestation of grain by this species. Temperature was less important; mites bred at temperatures as low as 40° F. The optimum was considered to be at 65° F.

A study of population dynamics by Solomon (41) showed warm temperatures and high humidities to be conducive to the rapid development of A. siro.

In a thesis, Ihde (12) discussed the biology of cheese mites and the effect of temperature and humidity on their development. In one experiment, the life histories of five species were compared at 55° F. and 100 percent r. h.

The longevity of adult male and female mites at 55° F. and 100 percent r. h. was studied in four species. The females lived slightly longer than the males, but the difference between species was very small.

In a series of experiments on the effect of temperature and relative humidity on the biology of A. siro, temperatures of 42° F. and 55° F. were combined with r. h. of 35, 55, 70, and 100 percent. The first experiment determined the effect on development. As the temperature or relative humidity was lowered, the development time increased for each life stage from the egg through the deutonymph.

A second experiment showed that lowering the relative humidity and increasing the temperature shortened the lives of A. siro.

A third experiment showed the effect of different temperature and humidity combinations on the longevity of A. siro confined without food. The results were similar to those obtained when the mites were confined on cheese.

The fourth experiment showed that no eggs were laid at either of the two lower humidities.

A final experiment showed the adverse effect of low relative humidity on the viability of A. siro eggs.

Robertson (29) reported that a temperature of 53. 6° to 57. 2° F. and a r. h. of 90 to 95 percent were ideal for the buildup of a population of cheese mites. A temperature of 41° to 42. 8° F. and a r. h. of 80 to 85 percent were not so good. Dutch cheeses stored under conditions ideal for mite buildup were not troubled with mites because of the process of oiling this type of cheese before storage.

With cultures on mold at 77° F., Rivard (26) studied the effects of r. h. of 70, 80, 90, and 100 percent on the rates of development and mortality of the immature stages of T. putrescentiae. At 60 percent r. h., no eggs were laid by the mites. Eggs laid at 70 percent r. h. and incubated at 60 percent all failed to hatch. Mortality in the egg stage ranged from 33 to 44 percent at the other humidities tested. Mortality in the other stages ranged from about 15 percent at 80 and 90 percent r. h. to 20 and 25 percent at 70 and 100 percent r. h., respectively. Average total development time was 12. 6 days at 100 percent r. h., 12. 2 days at 90 percent, 13. 9 days at 80 percent, and 18. 9 days at 70 percent. The males developed slightly faster than the females. Additional experiments in 1959 showed that at 70 percent r. h., mites survived longer than at higher humidities, and most of the males lived longer than the females. The preoviposition period averaged 2 days at 80, 90, and 100 percent r. h. and 3 days at 70 percent r. h., while the oviposition period ranged from an average of 36 days at 70 percent r. h. to 23 days at 100 percent. The rate of oviposition at 90 percent r. h. was more than twice as great as that at 70 percent, and intermediate rates of oviposition were observed at 80 and 100 percent r. h.

The hypopus stage of the cheese mites has been the subject of a great deal of discussion. Michael (17) discussed at some length the hypopus question. A summary of the literature in 1884 showd at least eight different definitions of the hypopus by various workers. The following definitions had been published:

1. "Hypopus is a separate family of adult Acarina."
2. "Hypopus is the immature stage of Gamasus."
3. "Hypopus is an itch mite."
4. "Hypopus is the adult of some species of Acaridae."
5. "Hypopus is a parasite, first internal and then external."
6. "Hypopus is a 'travelling dress'."

7. "Hypopus is the female of Acarus."

8. "Hypopus is the cuirassed, heteromorphous, adventitious nymph of Acarids, etc., appearing only for the distribution and preservation of the species under adverse conditions."

Michael discovered that a hypopus was a development stage, sometimes but not always present in the life cycle of mites. The hypopus formed by ecdysis from the protonymph stage. After another molt, it changed to a deutonymph. The hypopus was flattened and hardened. It was resistant to drought and heat that would easily destroy the other development stages of the mites. Michael found that the formation of hypopi was not due to unfavorable conditions, more hypopi seemingly being produced under ideal conditions. The hypopus was not parasitic, but attached itself to insects and other animals apparently for transportation.

Reuter (25) called the hypopus stage a "deutonymph" and the stage commonly known as the deutonymph was referred to as the "tritonymph". The "deutonymph" stage of Reuter (Hypopus) was described by him as an active migratory form.

Eales (6) reported finding the hypopus form of T. longior, but made no observations on its biology.

Schulze (32) found a Tenebrio molitor beetle with 700 hypopi of the species C. rodionovi attached. After further work (33) on A. siro, Schulze reported two types of hypopi, identified as Hypopus I and Hypopus II. The first was a motile form and the latter was an inert form. Hypopus I was considered a primary form of Hypopus II, and was less resistant to drying and cold temperatures than the latter. Oudemans (22) stated that the Hypopus II stage described by Schulze was the hypopus of Acarus farris and not A. siro, although it was conceded that the former species might be a degenerate form of the latter. Schulze (34) refuted Oudeman's view.

Schulze (35) also studied the factors relating to hypopus formation and the changing of the hypopus to a deutonymph in C. rodionovi. Some of the protonymphs, which were morphologically distinct from the others, formed hypopi independently of environment. Of the remaining protonymphs, many could be made to form hypopi by depriving them of suitable food. Temperature and relative humidity were found to have no effect on hypopus formation. Before a hypopus would molt into the deutonymph stage, environmental moisture greater than when the hypopus formed was necessary. At a temperature of 80.4° F. or higher, 100 percent of the hypopi changed to deutonymphs within 45 hours, while at 56.8° F., only 37.5 percent had become deutonymphs after 20 days.

Belyaev et al. (2) found the hypopi of A. siro and T. longior to be abundant in decayed seed with a 50-percent moisture content. When these hypopi were placed in media with 18-percent moisture content, adults were present in 4 to 8 days. Sokolov (42) found hypopi numerous under similar conditions. He reported that hypopi appeared in numbers only if the grain was moldy or very dirty.

Hora (10), working with G. domesticus, found that 50 percent of the protonymphs formed hypopi under ideal conditions of 77° F. and 90 percent r.h. Hora's studies showed the hypopus to be a resistant form, taking the place of the protonymph resting stage. Hypopi gave rise to deutonymphs that developed into normal female or male adults. The cause of hypopus formation was not discovered, but it was found not to be the result of abnormal environment or of overcrowding.

Debris collected from a stable by Jary (13) contained numerous mites. As the samples dried, many mites went into a hypopial stage, and when reared to adults were found to be A. siro. Jary (14) found frequent hypopus formation in Calaglyphus sp. reared at 68° to 69.8° F. In Eberhardia sp., they were less common under the same conditions.

Polezhaev (23) experimented with L. destructor to determine the cause of hypopus formation. Hypopi were less abundant at 80 percent r. h. than at higher or lower humidities. Removal of food for different lengths of time tended to check the appearance of hypopi and caused increased mortality. Polezhaev disagreed with Hora's view that outside conditions do not affect hypopus formation. Further work (24) on hypopus formation in L. destructor indicated that hypopi were scarce or absent under optimum conditions for mite development and were more numerous as conditions deviated from the optimum. Hypopi changed to deutonymphs only at temperatures above 53. 6° F. At high temperatures, a r. h. of 80 percent or higher was necessary for the transformation. Work with A. siro showed no hypopus formation at any time when the temperature was from 35. 6° to 86° F. or the r. h. was from 40 to 100 percent.

Zakhvatkin (47) stated that mite species fall into three classes with respect to hypopus formation. One group of species produces a small but rather constant number of hypopi. A second group of species always forms the hypopus stage. The third group of species forms hypopi only under undesirable environmental conditions such as drying, lack of food, deterioration of quality of food, and abnormal temperatures.

Ushatinskaya (44) studied the effect of temperature and r. h. on the formation of hypopi in L. destructor. At 32° F., no hypopi occurred, and at 41° F., only a few. A temperature of 50° F. produced 1. 8 percent hypopi in 78 days and 29. 1 percent in 200 days. With the exception of a few at 50° F., hypopi did not become deutonymphs unless the temperature was 53. 6° F. or higher. This caused an accumulation of hypopi at the lower temperatures. At temperatures of 77° and 86° F., not more than 0. 5 percent hypopi appeared. A moisture content in the grain of 13. 2 to 17. 2 percent (57-84 percent r. h.) was necessary for hypopus formation. Hypopus formation occurred most often at temperatures of 59° to 71. 6° F. and a moisture content of 16 to 16. 3 percent (80 percent r. h.).

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