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INSECTS INFESTING STORED FOOD PRODUCTS

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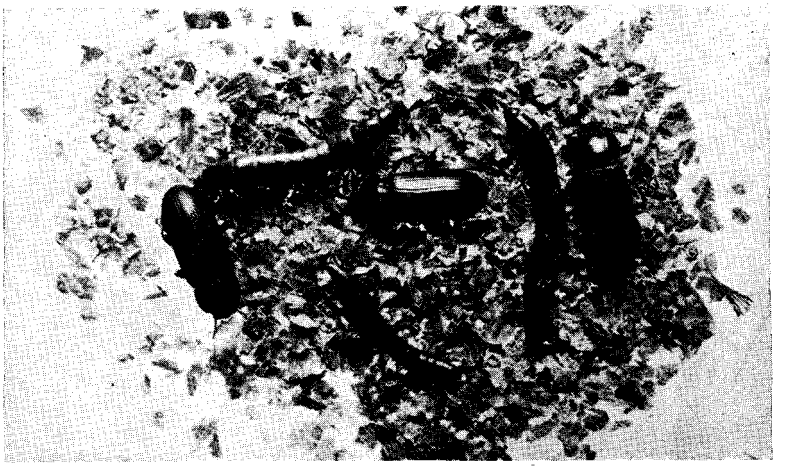

MEAL WORM, ADULTS AND LARVAE, IN BRAN (SLIGHTLY ENLARGED)

UNIVERSITY FARM, ST. PAUL

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INSECTS INFESTING STORED FOOD PRODUCTS

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INTRODUCTION

Purpose of the Bulletin

The object of this bulletin is to make it possible for any one who is troubled with insects in stored food products to determine for himself what insects they are, where they came from, and what to do to get rid of them.

Many insects are not described in these pages, or a special product may not have been discussed. For additional information write to the Division of Entomology and Economic Zoology, University Farm, St. Paul, Minnesota.

References are made to papers and bulletins which give more detailed information on some of the subjects. No attempt has been made to give a complete list of literature on any subject. The references given are chosen because they refer to publications easily obtainable and contain detailed information that can not be included in a small bulletin.

Treating the insect problems of the grain dealers, the millers, and others separately has necessitated a considerable amount of repetition. This gives each one concerned with the manufacture or distribution of food products a better understanding of his own problems and at the same time makes it possible for him to obtain a similar understanding of the problems of those who are co-workers with him in the handling of stored food products.

It is hoped that readers may have a better understanding of the causes of insect attack and that it may hasten the time when manufacturers and dealers will no longer believe that insects come from "the germ of the wheat" or from any other source than insect eggs. Then the problem of properly protecting our stored food from insects will be attacked from a more practical point of view.

How to Use the Bulletin

The special sections make it possible for seedsmen, grain dealers, millers, manufacturers, managers of warehouses and wholesale dealers, bakers, retail grocers, and housekeepers to get information about their own problems without having to read descriptions of situations in which they are not interested. Nevertheless, it is hoped that there will be many who will be sufficiently interested in the general problem of protecting stored food products from insects to read the whole bulletin.

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The eighth section deals with the insects themselves. The species of any insect found may be determined by using the table on page 34, unless the insect is of rare occurrence in Minnesota. Before trying to use the key, "Structure of a typical insect" and "Life history of a typical insect" should be read carefully. The habits and economic importance of the different insects are described following the table.

The last three chapters describe the general methods of combating the insects by the use of heat and fumigants, and methods of storing cereal products in order to keep them free from insects.

Losses Caused by Insects Attacking Stored Food Products

No accurate statistics are available on the total amount of damage caused by insects to stored food products. It has been estimated at about 5 per cent of the total value, or $200,000,000 each year, in the United States. Even this gives no adequate idea of the situation, for the reputation of cereals has often been damaged by the presence of insects in them when they reached the trade. In many cases the entire business of a cereal company has been ruined because the buying public found insects in the product. The amount of food products eaten by insects may be fairly large in the aggregate, but it is relatively insignificant as compared with the amount rendered unfit or undesirable for human consumption by the mere presence of insects.

The enormous loss represents one of our greatest economic wastes for two reasons: (1) It represents not only the loss of a certain amount of grain but also the loss of the labor of agriculture, manufacture, and trade which has contributed to the harvesting, milling, and handling of the product. (2) It is entirely possible to reduce this loss to an almost negligible minimum.

General Causes of Losses and Methods of Prevention

The insects that destroy stored food products get into the products after the cereal has been grown and while it is in the process of being harvested, milled, or distributed. The accompanying illustration shows the main steps in the handling of cereal products from the time the grain is stored in the granary until the finished product has been finally taken to the home of the consumer. At each step there is a possibility of its becoming infested if proper precautions are not taken. The essential precaution is simply to prevent any insects from getting into the cereal and laying eggs. If this one precaution were observed, there would never be any loss of these products from insects.

Carelessness in one of the steps in handling the product may cause it to become infested, even tho due precautions have been taken in

Fig. 1. Course of Cereal Products from the Farm to the Consumer

Food Must Be Protected from Insects at Every Handling from Farm to Consumer

Granaries should be thoroly cleaned before being filled in the fall. Small accumulations of grain in the corners cost farmers thousands of bushels of weeviled grain every year.

Elevators often harbor insects in the refuse on floors and beams and in corners. They should be thoroly cleaned and fumigated if they are badly infested.

Mills may be infested with flour moths and beetles which, if not controlled, will be shipped to all dealers and will spread the infestation. Cleanliness and heating or fumigation will eliminate the trouble in the mills as well as much that occurs in warehouses and stores.

Freight cars, when uncleaned, will infest all products shipped in them and spread the infestation to the destination of the shipment. Clean all cars carefully before loading them.

Warehouses are a serious source of infestation for all goods stored in them if they are not properly cleaned or if infested goods are allowed to enter them. When they are properly cleaned and no infested goods are accepted for storage, they are perfectly safe.

Wholesale houses are much like warehouses. They must be kept clean and the old stock must be moved out before new stock is put in to cover it.

Retail stores are in contact with the consuming public and must look and be clean. If the goods becomes infested here, all precautions taken in the previous handling of the product may be of no avail. No infested food product should be permitted in a retail grocery store.

The home may become infested by some "wormy" product that has been put up in the cupboard, and the insects may crawl into new packages as soon as they are opened.

all other steps. The most common assumption is that the firm whose name appears on the package is fully responsible for any insects found in the products at any time. When the manufacturer keeps his mill clean, "sterilizes" his product and seals it in clean substantial packages, he discharges his duty, but his product is still subject to handling in a series of places. In any one of these some of the packages may become broken or insects may be present which will eat their way into them. In contrast to this condition, a dealer may keep his place perfectly clean and free from insects, but may receive shipments of stock from infested mills or from other dealers who have not taken proper precautions, and thus in spite of all his efforts insects sometimes get into his place because of the neglect of others. A certain amount of responsibility rests upon each one who takes part in the handling or storing of cereal products in that he should never pass on an infested product to contaminate other products or other places where cereal products are stored and handled.

INSECT PROBLEMS OF SEEDSMEN

Losses That Insects May Cause To Seedsmen

Seedsmen deal with a product that is to be grown rather than eaten. Any injury that prevents germination and growth of the seeds causes a total loss. Some insects destroy the entire seed; others only the germ; in either case the product is a total loss so far as its value as seed is concerned. In addition to this actual destruction, planters hesitate to deal with seedsmen when they know they handle seed that is infested in even the slightest degree. In the case of many insects, a few in the seed may mean a high percentage of infestation at the time of harvest. This is because some insects, such as the bean weevil, emerge from the seed in the field and later lay their eggs in the developing beans. Therefore the reputation of a seedsman is at stake whenever there are insects in his establishment.

Beans and peas have been the cause of much trouble to seedsmen and others who keep them in storage. The insects often leave the germ to be eaten last or avoid it altogether. Consequently, while the weevils are common and destructive, germination tests of seeds that have been treated as soon as the injury was discovered usually make a good showing. The seedlings, however, may be backward because the nourishment has been lost. In wheat and some other seeds the injury may not be apparent from a superficial examination, and the germination test must be relied upon in determining the extent of damage caused by insects.

How Insects Get Into Storehouses of Seedsmen

As a rule it is only the insects that actually attack the seeds that get into seedhouses; consequently, with few exceptions, those that attack seeds in the seedhouse live in these places rather than in the field. Those that attack other parts of the plants usually spend the winter in the field where the crop is grown. The rice weevil, the angoumois grain moth, and a few others may be brought in from the field. Careful inspection will reveal some of the insects, but others may be hidden in the center of the seed, only to come out later and move to other seeds.

The variety and number of insects that the seedsman should watch for when examining a shipment varies greatly with the different seeds. He should be suspicious of all insects found in his seeds and tolerate none.

Conditions That Make It Possible for Insects to Exist in Seedhouses

Temperature and moisture conditions of seedhouses are usually favorable to insects. Temperatures between 40 and 50 degrees Fahrenheit allow very little development of the insects, while lower temperatures practically stop development, but if the seeds are later brought to a higher temperature, development will usually go on. Insects develop most rapidly at about 80 or 90 degrees F. Few insects will develop normally at temperatures higher than 100 degrees, most insects will die in a temperature of 120 degrees in a few hours, and few can stand a temperature of 140 degrees for even a very short time.

Moisture affects insects in about the same way that temperature does, too much or too little will prevent their development; ordinary amounts produce the most rapid development. The seedsman must try to keep the conditions of his seedhouse such that they will be favorable to seeds but unfavorable to insects. A temperature below 40 degrees F. makes it impossible for insects to develop and at the same time will not injure the seed.

The insects might be divided into two groups according to their method of feeding. Those of one group remain in the seed until they reach the adult stage; those of the other group go from seed to seed and may eat only the germ. Some of the insects in the first group do not emerge until the seed has been planted. They do not increase in numbers while in storage. The pea weevil is an example. While the damage caused by these insects is not so noticeable as that caused by some others, it is often deceiving. Sometimes they come out in the early spring and the seeds in which they are can be condemned or treated. But very often their presence is not suspected and the seeds-

man may sell infested seed without knowing it and his customer may lose his crop as a result.

Insects that develop in the seedhouse increase in numbers when conditions are favorable, and by going from seed to seed cause a great deal of damage, which is very evident if the seeds are inspected occasionally. Bean weevils are an example. They pass through generation after generation inside the seeds while in storage. The Indian meal moth is an example of those that go from seed to seed eating only the germ.

The policy of keeping over old seed must be decided by knowing what kind of insects they are likely to contain. When infested with insects that can not pass a second generation in the storehouse, they may be kept until the second year, and all the insects will have died by that time. These insects can not spread to other lots of seed because they can not start a new generation until they get out into the field. But if there are insects that can produce new generations while in storage, it will be dangerous to have the seed around.

INSECTS OF SPECIAL INTEREST TO SEEDSMEN

Miscellaneous insects—
- Cockroaches
- Ants
- Lepismids
- Book lice
- Mites

Beetles—
- Granary weevils
- Rice weevils
- Bean weevils
- Pea weevils
- Square-necked grain beetles
- Saw-toothed beetles
- Drugstore beetles
- Large cabinet beetles
- Small cabinet beetles
- Museum beetles

Moths—
- Angoumois grain moths
- Indian meal moths

INSECT PROBLEMS OF MILLERS AND GRAIN DEALERS

Losses Caused to Grain Dealers and Elevator Managers

The presence of insects in grain reduces its value, and makes its keeping qualities questionable. It is dangerous to store infested grain near sound grain for it gives the insects a chance to spread. A few insects in the grain when it is put in storage may increase in numbers and by their feeding activities cause the grain to heat, with the result that all the grain will be injured if not entirely lost.

The official grain standards of the United States and the "Minnesota Grades" instruct the federal and state grain inspectors to classify grain "infested with live weevils or other insects injurious to stored grain" as "sample grade." In the reports of grain inspectors the term "bran bugs" has been substituted for the expression "other insects injurious to stored grain." Therefore any insect that is considered to be in-

jurious to stored grain, which is not a weevil, is called a "bran bug." Grain is often shipped to the terminal elevators by country elevators with the expectation that it will be graded as "No. 1," only to have it reported as "sample grade because of weevils." In such cases the price of the grain may be greatly reduced. Wheat has sold for $150 a car less than was expected because of this.

The reason for this prejudice is the hazard of storing grain that is infested with live insects. Entire stores of grain might be infested and destroyed as a result of allowing a small amount of weevily grain to be unloaded into an elevator.

The grain may be fumigated and all the insects killed to avoid having it classed as "sample grade." This may be done in the freight car and even after it has been once inspected and classed as sample grade. Instructions for fumigation are given on page 72.

The species of insects that attack sound grain are relatively few and can not do any appreciable amount of damage in milled products, but a considerable number of insects follow along after those that attack sound grain. These secondary insects feed upon the hulls left by the others and may aid in causing the grain to heat. They also work in milled products and are a serious pest in mills.

How Insects Get into Elevators and Granaries

The great majority of insects found in elevators and granaries spend their lives in these places, living on refuse grain, and in crevices when the bins are empty. When the place is filled with grain the insects crawl into it and multiply. A very few insects, as the angoumois grain moth and the rice weevil, may enter the grain before it is threshed and be brought to the granary with it, but these are the exceptions. In Minnesota the grain insects are largely limited to the granary and the elevator, because of the low temperatures during the winter.

Modern concrete elevators are easily cleaned and may be kept free from insects with little effort. Wooden buildings with cracks and crevices are much more dangerous and require careful cleaning before being refilled. Careful cleaning each season will reduce the trouble from insects as nothing else will, and the little time spent each year may save a heavy loss of grain and a much longer time in freeing the place from insects after they have become established.

Conditions That Make It Possible for Insects to Live in Granaries and Elevators

In Minnesota the problem is how insects stay in granaries rather than how they get into them. Other things being favorable, insects can live only where temperature and moisture conditions are within certain

limits and where food is present. Fortunately, temperature conditions in Minnesota are such that there can be little or no development of insects in unheated storehouses during the winter. Grain may be put into storage at a high temperature and it may maintain this temperature long enough for the insects to pass through one or more generations, but this is unusual, especially in the case of grain grown in the northern climate.

Prior to the summer of 1921 the Minnesota State Board of Grain Inspection had no records of weevils in Minnesota spring wheat. They had always been shipped to terminal elevators from the southern states but they apparently had never been able to survive the cold winters. The same might also be said of the other insects, or bran bugs.

The year 1921 was a marked exception, for infested grain was common throughout the southwestern part of the state, presumably because of the mild winter, the large amount of grain held over, and the hot weather during the early part of the summer. These insects were found in the granaries on the farms and in the country and terminal elevators.

When the temperature of the grain remains below 40 to 50 degrees there is no danger of further damage, but if the temperature rises the insects become active in a short time. Grain that has been kept for some time and not heated often has very little oxygen near the center of the mass and this lack of oxygen may reduce the number of insects. For this reason it is not wise to take grain out of storage and air it when there is no evidence of its heating.

Losses That Insects Cause to Millers

Insects cause losses to millers by destroying their products, by spinning webs and clogging the machinery, and by damaging the reputation of the products when they come to the attention of customers.

A miller can hardly estimate the loss to his reputation that may be caused by a very few insects that could not do any appreciable damage to the products themselves. For this reason, even in cases where the insects can not be said to "bother," it may be necessary to give them the closest attention in order to maintain a reputation for products that are above reproach. Customers are very ready to blame all insect trouble on the miller even in cases where it is very evident that the source of the difficulty is in the retail grocery. In such cases the best proof of innocence the miller can produce is an establishment free from insects.

The volume of business, the construction of the building, and the

amount of dust constantly accumulating in a mill make it a very favorable place for insects, and a difficult place in which to combat them.

Conditions That Make It Possible for Insects to Get into Mills

So far as milled products are concerned, the miller stands very near to the source of insects when compared with the various dealers who pass these products on to the ultimate consumer. None of the insects that attack the raw material—the unmilled grain—do any considerable damage to the milled products, but it is important to distinguish between the insects that attack the sound grain and those that follow them and work in the damaged grain. The latter work in the milled products and are often very injurious. Those that attack the sound grain "grind" it, and the material left is very much like that which comes from the mill, so far as the ability of other insects to attack it is concerned.

It is of greatest importance that the miller should fully realize the danger of buying grain that has been damaged to any extent by insects. It may contain some of the insects that follow those that attack the sound grain and the mill may become badly infested.

Insects that live in mills are largely confined to the mills or the warehouses and stores through which the milled products pass on their way to the consumer. They are passed from one mill to another in empty sacks that are exchanged or returned.

For this reason the miller must watch all the material that comes to the mill, including the empty sacks, and also the mill itself to see that it is not a center of infestation. For the sake of his business he must watch the products that go out in order that they may not endanger the business of his customers.

It is not difficult to avoid getting grain that contains insects, for the grain inspection, or inspection on the part of the miller, can give protection against this source. Returned sacks and other materials are much harder to control. Insect eggs are not easily seen and sacks may pass as free from insects when they contain thousands of eggs that will hatch in a few days. Furthermore, an ordinary cleaning of sacks may remove all the insects but leave the eggs. The only safe method is to fumigate or heat them when they are returned and before they are brought into the mill. A little time spent in treating the sacks will save much time in trying to rid the mill of the insects after they once get in.

INSECTS OF SPECIAL INTEREST TO MILLERS AND DEALERS IN GRAIN

Miscellaneous insects—
- Cockroaches
- Ants
- Book lice
- Lepismids
- Mites

Beetles—
- Primarily in unmilled grain, elevator insects:
  - Granary weevils
  - Rice weevils
  - Drugstore beetles
  - Square-necked grain beetles
- Primarily in coarse products, bran, meal, etc.:
  - Saw-toothed beetles
  - Cadelles
  - Meal worms
  - Flat grain beetles
  - Foreign grain beetles
- Primarily in flour:
  - Confused flour beetles
  - Broad-horned and slender-horned flour beetles
  - Small-eyed flour beetles
- Found in various parts of the mill:
  - Black carpet beetles
  - Cabinet beetles
  - Small cabinet beetles
  - Museum beetles

Moths—
- Primarily in unmilled grain. elevator moths:
  - Angoumois grain moths
- Primarily in coarse milled products, bran, meal, etc.:
  - Indian meal moths
  - Meal snout moths
- Primarily in flour:
  - Mediterranean flour moths

Conditions That Make It Possible for Insects to Live in Mills

With the more or less constant temperature of the modern mill and the ever-present supply of food, conditions are usually favorable for the development of insects. When the temperature drops below 40 or 50 degrees F., development is practically stopped, but at higher temperatures, especially from 80 to 90 degrees, the development is very rapid. Insects are unable to live at extremely high temperatures. Very few of them can endure a temperature of 120 degrees for even a few hours, and a temperature of 140 degrees is fatal to practically all insects in a very short time.

Moisture conditions affect insects very much as temperature conditions do. Ordinary humidity is most favorable to insects, but when it is very low or very high they can not survive long. Food that contains less than 7 or 8 per cent of moisture is too dry and hard for most insects and it is said that there are some that can not live in flour containing less than 11 per cent of moisture. When the moisture content gets too high they are usually affected more by the molds that develop in the material than by the moisture itself. However, it is possible in some cases to get the humidity so high that water will collect on the insects, then it is usually fatal.

As already mentioned, the construction of a mill and the dust that is constantly accumulating make it a favorable place for insects to live in and a rather hard place in which to combat them. When floors and walls are so tight that there are no cracks, when all conveyors and hoppers are so constructed that flour will not accumulate in inaccessible places, and when all machinery is placed high enough above the floor that it will not interfere with thoro sweeping, a mill can be kept so clean that insects will find it difficult to live in it..

INSECT PROBLEMS OF MANUFACTURERS OF SPECIAL PRODUCTS—BREAKFAST FOODS, MACARONI, PANCAKE FLOUR, DRUGS

It might be better to discuss the advantages of being able to guarantee products to be free from insects rather than the losses they cause to manufacturers of special food products.

Special products put up in packages cost more than ordinary bulk foods because they are clean and are made of selected materials. Customers are usually willing to pay the extra cost of packing when they know that the product is clean, but if the products show the slightest evidence of insect injury, they are at once robbed of their superior character and can not compete in the market with bulk products. For this reason the manufacturer of any special food product can not neglect the insect question. On the other hand, most manufacturers take pride in advertising their product as superior in that it is guaranteed to be free from insects.

The amount of material destroyed by insects in manufacturing establishments is usually not very great, but cases have come to the attention of the writer that involved the loss of large consignments of raw material. The most serious aspect of the matter is the one already mentioned, namely, the reputation of the product. Perhaps no other class of manufacturers is trying harder to solve the insect problem than that concerned with these special products, and the following descriptions and instructions will be helpful to them.

How Insects Get into Factories

It must never be forgotten that all insects come from eggs, just as chickens do, and that an insect can not develop from meal or any other material any more than a chicken can. If insects appear in a factory or storehouse it means that either insects or insect eggs got into the place in some way.

One of the principal means of infestation is the raw material. Insects that attack sound grain do not do any appreciable harm to breakfast foods, meals, and flour, but those that attack grain that has already been damaged are serious pests of flour. Hard products, such as macaroni, and some biscuits, are often attacked by the same insects that attack sound grain. In any case it is a risk to allow infested material to come into the factory, for if the insects once become established it is difficult to get rid of them.

Insects usually get into factories in returned sacks and other containers that may come back to the place for refilling, or in damaged goods that have been returned. Nothing should be allowed in the establishment until it has been thoroly inspected. Goods returned for any reason should not be taken into the factory. Mere inspection of

sacks and other containers is not sufficient, because the eggs are very hard to detect. The only safe method is to fumigate or heat them, as will be described later. Keeping insects out will solve the whole problem.

Conditions That Make It Possible for Insects to Live in Factories

Insects can ordinarily live wherever there is a certain amount of heat and moisture and enough suitable food. Conditions usually found in factories are favorable for their growth and reproduction. When the temperature gets below 40 or 45 degrees F. there can be little or no insect development. The rate of development increases with the rise of temperature until the heat becomes injurious, a little above 100 degrees F. Few insects can stand a temperature of over 120 degrees F. for more than a short time and a temperature of more than 140 degrees is fatal to practically all insects in even the shortest time.

Moisture conditions affect insects much as temperature conditions do, too little or too much moisture may be injurious, but a certain amount is necessary for normal growth and reproduction. Few insects can live in food containing less than 6 or 7 per cent moisture and some are said to be unable to eat material containing less than 11 per cent moisture. A high moisture content usually causes molds to grow on the food. However, when conditions are such that water collects on the insects they are usually unable to live.

The unfortunate thing in connection with both temperature and humidity is that the usual conditions are the most favorable ones for the rapid development of insects. Conditions that will kill insects are so extreme that it is seldom possible to bring them about except for a short time when the insects have become numerous.

The control of available food is more practical than the control of conditions. Accumulations of flour or other material in cracks or corners make it possible for insects to develop, reproduce, and go to all parts of the establishment. When no such accumulations are allowed and the stocks of cereal are kept clean and are changed often, the insects will have no food in which to develop and the place can be kept free from them. It is important to see that the place is actually clean and that no places are being overlooked, for even a small amount of material in an out-of-the-way place can cause a great deal of trouble.

How to Keep Insects Out of Factories

First of all, the factory must be kept clean. There is no use in trying to keep insects out of a dirty factory. All accumulations of flour and dust must be kept off the floor. All machinery should be so built that the floor beneath it can be kept clean, and storage room should be so arranged that it is possible to sweep under the stock and prevent the accumulation of flour under or between the packages of goods.

Second only to cleanliness is the necessity for inspecting all raw materials and returned sacks before they are brought into the factory. Any web or silk on a sack means that moths are in it or have been. Any movement of the particles of material indicates insects. Dust-like material in the bottom of sacks is indirect evidence of their presence. When a lot of material is suspected it should be put in a quarantine room and samples taken for careful examination. A small amount may be left in a glass tumbler over night. Little holes and burrows next to the glass in the morning are good evidence that the material is infested. Another good method is to smooth off the top of the material in a sack and leave it over night. If there are insects present, the top will be filled with little holes and burrows in the morning.

A quarantine room should be provided so that all suspected material can be removed from the regular storerooms as soon as its condition is questioned. Storerooms have become completely infested because of a small amount of infested material that the owner neglected to isolate. During hot weather it is dangerous to leave the material near other stock for even a short time, because of the increased rate of insect development.

All material that has been quarantined should be heated or fumigated before it is released. Directions will be found on page 66. After material is treated it may be sold for stock food. Insects can be sifted out only when the particles of the material are smaller than the insects.

When a factory has become thoroly infested, the only thing to do is to give it a thoro cleaning and then either fumigate the whole establishment or heat it. This is quite a task but it is the only way to get rid of the pests and be able again to produce foods that are known to be free from insects. General directions for these processes are given on pages 70 and 74.

INSECT PROBLEMS OF TRANSPORTATION COMPANIES

Railroad box cars in which grain and food products are shipped are often made with double walls having considerable space between. Insects from an infested shipment may crawl between the walls, feeding there in accumulations of grain and entering later shipments that were originally free of pests. Cars should be thoroly cleaned before re-loading, as also should boats that carry such material. If it is impossible to clean them thoroly, they may be fumigated as described on page 74. The doors should be tightly closed and the gas allowed to act for 8 or 10 hours before airing.

Sometimes a shipment in bags is found to have beetles on the outside of the bags. These may be removed with hand brushes. When

flour itself is infested it may be reconditioned and sterilized in mills equipped for this work.

Often the carrier is blamed for the infestation of shipments in its care. In order to place the responsibility for such damage it is necessary to determine the history of the shipment, the species of insect involved, and the stage in which it was when detected. Different species of insects have differing habits and require different lengths of time to develop at ordinary temperatures. An intimate knowledge of the details of the life history of the insects is required in order to trace accurately the origin of an infestation. It is best in each case to seek the advice of an entomologist.

INSECT PROBLEMS OF WAREHOUSEMEN AND WHOLESALE GROCERS

How Insects Get into Wholesale Groceries and Warehouses

If insects are found in a warehouse, they came in, presumably, with goods. This does not mean that all the insects found in the storerooms of a wholesale grocer came from the companies from which the goods were purchased, and that the wholesale grocer himself has no responsibility. He has two problems: one concerned with the bringing in of insects, the other with their growth and reproduction on his premises. The wholesale grocer shares the responsiblity of the first problem with the persons from whom he buys.

All goods should be carefully inspected when they are brought into the warehouses and should not be accepted if they contain insects. It is practically impossible, however, to discover eggs in them; therefore the consignor is not entirely responsible for insects that he may ship. There may be eggs in the goods while they are in his possession, but he can not be aware of them. However, by the time the goods reach the consignee the eggs may be hatched, and the wholesale grocer may find the insects when he examines the goods, hence his responsiblity in making the examination.

Breakfast foods, coarse flours, meals, dried fruits, rice, and similar goods should be carefully examined. Nearly all breakfast foods sold in sealed packages are heated at the time of packing, and if the packages are clean and unbroken it may be assumed that they are free from insects. Those that come in bulk are most liable to infestation and should be watched, not only when they are received but as long as they are in the warehouse.

Any web or silk on the sides of the package or stretching between particles of the material, or any movement in the particles, means that moths are present. Usually the insects themselves can be seen, or if

the material has been left undisturbed for a time tracks or little holes can be seen in the surface.

It is only fair to notify the consignor of any trouble and it is his duty to take greater precautions.

Conditions That Make It Possible for Insects to Live in Warehouses

A few insects in a warehouse can cause a great deal of trouble, and it is much harder to get rid of them than to keep them out. There is plenty of food and the place is often sufficiently warm and moist for them to grow and reproduce rapidly. Small amounts of flour and meal in corners and on rafters will support a population of insects that will be ready to move into the new goods as fast as they come into the room. The first and most important thing to do is to keep the place clean; next, not to keep goods on hand for long periods of time, for insects may overrun the place if they are given time to reproduce.

The temperature of the storeroom influences the rapidity with which the insects grow and reproduce. Development is very slow between 40 and 50 degrees F. while at lower temperatures there is practically no development. The rates of growth and reproduction become more rapid as the temperature rises until it gets a little above 100 degrees F. Few insects can stand 120 degrees for more than a short time, and a temperature of 140 degrees F. is fatal to practically all insects. It is evident that ordinary summer temperatures are most favorable for the rapid growth of insects and that both the high and low temperatures that will prevent growth are rather unusual.

Moisture affects insects in very much the same way that temperature does; too much or too little may prevent development, but a certain amount is necessary for the most rapid growth. Again, the amount of moisture that will cause the most rapid growth is about the usual amount to be found in stored food products, and the high and low limits that prevent growth are unusual. Low moisture content often makes the food so hard that the insects can not eat it, and high moisture content usually affects the insects by causing the food to mold. Neither of these conditions is good, but of the two, low moisture is to be preferred, at least for breakfast foods and many others that can be protected from both insects and mold by being kept dry. Insects grow rapidly when the relative humidity of the air is about 70 per cent, and in such foods as meals and flour when they contain from 11 to 14 per cent of moisture. If there are many insects in the food the moisture that they give off in breathing will increase the moisture content to such an extent that the food may soon become moldy.

Thus it may be seen that under usual conditions a warehouse is a good place for insects, and that in order to avoid trouble with them it is necessary to keep them from getting in, or to make conditions so unusual that they can not live. This will be taken up under another holding. (Pages 66 and following.)

Damage Caused by Insects in Warehouses

Insects cause losses to wholesale grocers in two ways—by injuring both their goods and their reputation. A few insects may injure the reputation of a dealer more than the goods, hence no retail dealer should risk introducing infested stock into his store. However, it often happens that goods are ruined in a short time when the weather is warm, and more often goods that were in the best of condition become hardly salable because they show signs of infestation.

A retail grocer can not be blamed for refusing to buy of a wholesale dealer whose establishment he suspects of having insects, when he can get goods from a source that he knows to be free from insects. A few insects, not enough to do any appreciable harm to goods, may be seen by a customer and cause the loss of a considerable amount of trade, because of prejudice. For example, a dealer stated that all products from a certain source were infested with insects and he based his statement on a single experience. When the source was inspected, it was found to be even more free from insects than the average wholesale house. However, the risk in buying from a source known to have insects is so great that the retailer is justified in being cautious.

How to Keep Insects Out of Stored Food Products in Wholesale Houses

Proper inspection of consignments received, cleanliness in the warehouse, and management of the stock to prevent long storage during hot weather are essential to keeping insects out of warehouses. These methods of prevention are worth more than all known methods of eradicating insects after they once get in.

For the purpose of inspecting a consignment, a few representative sacks or packages can be chosen for a careful examination. If these are free from all web or silk and show no marks of insect work, it may be assumed that the entire lot is free from insects. If some of the sealed packages have tiny holes in them they should be opened and, if insects are found, the whole lot should be inspected. In rice and other whole grains there will be some fine material in the bottom of the sacks and holes in some of the grains. Dried fruits may have insects in the center of the package. Dried fruits are usually heated at the time of packing but they often are infested later. Sometimes in-

fested packages of dried fruit are unwrapped and the mass of fruit dipped in boiling water. This kills only the insects on the outside of the fruit. These are usually washed off and it may pass for first-class goods for a time but later the insects will again work out from the inside.

In each warehouse there should be a quarantine room, separated from the rest of the establishment and so built that it can be closed tight. It should also be equipped with sufficient radiation that it can be heated to a temperature of 130 degrees F. Such a room may save large quantities of food from depreciating in value if not from destruction. All infested material or material suspected of being infested should be put in this room as soon as its condition is discovered. Only stock that is known to be sound should be in the regular warehouse. Such practice will prevent any insects from becoming established and will make for a reputation for dependable goods.

The matter of cleanliness about the warehouse can not be overemphasized. All material, sacks, cartons, and other packages should be stored on supports high enough to allow the floor to be well swept. Flour or dust that falls down between the sacks and packages should be swept up frequently. No refuse should be allowed to accumulate between packages. Corners and crevices and the tops of beams should be cleaned often, for insects can breed in small amounts of flour in such places and then go to all parts of the establishment.

Piles of stock should be so arranged that all old stock is removed before later consignments. If goods are removed from the side of the pile rather than the front, new consignments can be piled by the side of the old instead of in front. This will leave the old stock always accessible at one side.

It is good practice to keep the stock low in warm weather. As has been said, insects multiply very rapidly at summer temperatures. It is often possible to put goods in cold storage, which prevents development of the insects. If a room can be kept at a temperature of 40 degrees F. and still be dry, there will be practically no insect growth. However, in nearly all cases the insects will remain alive and when the material is again brought to a higher temperature will resume their development. Of course, if there are no insects in the material when it is put into storage, it will remain free from them, if there are none in the cold-storage house. Cold storage should be used primarily to keep goods free from insects and not for keeping goods already infested.

If all goods are inspected upon arrival and only sound material is received, and if all material is removed to a quarantine room as soon as it is even suspected of being infested, there will be little trouble if the warehouse is properly cleaned.

Material removed from a warehouse should be fumigated or heated in order to kill all insects. Directions for fumigation and heat treatmen are given on page 66. Material that is only slightly infested may be salvaged if it is possible to sift it through a screen fine enough to keep the insects from passing through. Such material will, of course, still contain the excrement of the insects. To separate all insects, a No. 9 standard bolting cloth is necessary, and this is so fine that it will exclude practically all but the patent flours. This means that salvaging is very difficult and it is always a questionable practice when the reputation of a business is valued.

Aside from insects that attack the food itself, others are often troublesome. Cockroaches may be exterminated by the careful and thoro use of commercial sodium fluoride. This material may be dusted into all cracks and corners and in all places where roaches have been seen. It is essential that the powder be used in all parts of the establishment at the same time in order that the roaches can not escape. If this practice is continued for a time the place will soon be cleared of roaches. The same method may be used for firebrats. Methods of exterminating ants are discussed on page 62.

INSECTS OF SPECIAL INTEREST TO WHOLESALE DEALERS IN GROCERIES, DRIED FRUITS, FLOUR, AND OTHER FOODS

Miscellaneous insects—
- Cockroaches
- Ants
- Book lice
- Mites
- Cheese skippers
- Lepismids

Beetles—
- Confused flour beetles
- Saw-toothed beetles
- Cadelles
- Meal worms
- Drugstore beetles
- Spider beetles
- Cigarette beetles
- Larder beetles
- Red-legged ham beetles
- Bean weevils
- Pea weevils
- Rice weevils
- Granary weevils

Moths—
- Indian meal moths
- Mediterranean flour moths
- Meal snout-moths
- Angoumois grain moths

INSECT PROBLEMS OF RETAIL GROCERS

Losses Caused by Insects to Retail Grocers

Like all others who have to do with the preparation or sale of stored food products, the retail grocer may suffer losses in two ways: insects may attack his goods and ruin them, or they may be seen in his store or in his goods and thus cause a loss of reputation and trade. It takes a considerable number of insects to destroy an appreciable amount of groceries, but if a customer sees one insect in the food when about to eat it, or if he finds the slightest trace of insect work, he is likely to return the goods and discontinue his trade. The nature of a retail

grocer's business is such that much of his goods must be continually on display and any insects are likely to be seen by the customers.

Since the goods have come through the hands of several dealers, any eggs that may have been in the goods from the beginning are likely to be hatched by the time they reach the retail store or soon after. Furthermore, each transfer of the goods has added another opportunity for insects to get into them. As a result, insects are more likely to be found in a retail store, or to be seen if there, than in either the factory or the warehouse.

How Insects Get into Retail Grocery Stores

It can not be repeated too often that insects can not develop from anything but insect eggs and that nothing but insects can lay insect eggs. Therefore, when insects appear in grocery stores they come in as either eggs or insects. The most natural way is in consignments of groceries. If everything that comes in is examined carefully the insects may be found and the goods rejected. However, the eggs are so small that it is practically impossible to find them. For this reason a wholesale dealer may ship goods that he believes to be free from insects and yet when they reach the retail grocer they may be filled with larvae.

If insects are found in the food when it arrives, the case can be referred to the wholesale dealer, but eggs may be present when nothing else is found. Larvae may develop a few days later, but the blame can not be put on the wholesale dealer unless the retailer can show that there has been no opportunity for the insects to get into the goods after they have come into his possession. Thus, while insects in a retail store must have come from somewhere else originally, the retail grocer himself carries a certain amount of responsibility for those found in his store at any time.

Conditions That Make It Possible for Insects to Live in Retail Grocery Stores

The conditions under which insects live are the same wherever they are found, but the ways in which their requirements may be met are not always the same. Much that has been said about the wholesale grocery can be said about the retail grocery. Insects must have proper conditions of temperature and moisture in order to grow and reproduce, and these are usually favorable in grocery stores. It is seldom convenient to raise the temperature to 120 degrees F. or to lower it to less than 40 degrees in order to prevent insects from developing.

Insects can not develop and reproduce without food. When groceries are kept on hand for only a short time the insects have little chance to get into them and the goods are always fresh. When no

material is allowed to accumulate in corners, insects have no places in which to breed. Small amounts of old breakfast food and a few unswept corners are the most common sources of insects in groceries, and nothing can be more important than keeping both out of the store, for, without them, insects have little chance to live.

How to Keep Insects Out of Groceries in a Retail Store

The most important things for a retail grocer in protecting his stock from insects are (1) to accept only fresh, clean stock and (2) to keep his store clean and his stock always fresh. Unless these two things are done it is hopeless to try to keep insects out of the store and all who trade at a store where such care is not taken run the risk of having their homes infested.

The retail grocer should examine carefully some representative packages from each consignment of goods in order to see if there is any web on the sides or traces of insects in the material itself. It is often well to smooth off the surface of bulk meals or breakfast foods and leave them over night. If insects or mites are present the surface will be filled with holes and tracks in the morning. Look in the middle of one or two representative packages of dried fruit and see if there are any insects, or little pellets, which are signs of insect work. All sealed packages should be watched for holes. A few packages may be taken out of the lot and examined carefully. If there are even very small pinholes the packages should be opened and searched for webs and insects. If there are no holes the packages may be assumed to be free from insects and should not be opened, for opening them will make it possible for insects to get in.

After the retail dealer has discharged his duty in examining his goods, there is still the chance that there were some insect eggs that he could not detect. If anything develops within a few days, he should notify the wholesale dealer from whom the product came.

All effort made in inspecting the goods upon their arrival will be lost if the store itself is not free from insects. Any material found to contain insects should be **removed from the store** at once and fumigated, heated, or better still, if it is badly infested, burned. The writer has inspected stores where badly infested material was standing on the shelves and the insects could be seen crawling to fresh, clean goods near at hand. In this case the proprietor tried to excuse himself by saying that the insects were in the material when it came and that he intended to object to the salesman as soon as he came. In the meantime the insects had infested the whole store.

Flour should be stored on supports above the floor so that it will be possible to sweep under it. If storerooms can be kept dry and at a

temperature of 40 to 50 degrees F., or lower, groceries can be kept with very little danger of insect injury. Such cool rooms often become damp and should be watched carefully.

If insects have once gotten into the grocery store the condition may be serious. First of all the entire stock should be gone over and material that shows any signs of infestation should be removed to a quarantine room, which should be tight and separated from the rest of the store. All quarantined material should be fumigated or heated in this room in accordance with the directions on pages 66 and 72.

If the amount of material infested is small, it may be placed in a tight can or box and fumigated with ethylene dicloride. It is often advisable to use heat for small amounts of material.

After all the material known to be infested has been removed, the entire store should be carefully cleaned, and painted if possible. For several weeks after, it is well to keep a close watch for insects that may have hatched from eggs that escaped the process of cleaning. If the paint is applied with an air brush all cracks can be well filled.

If cockroaches are found, commercial sodium fluoride should be dusted all about the mopboards, in all cracks, and on all shelves where they have been seen. If this is done throughout the premises, in the basement and in all places where the roaches run, the entire place may be rid of them. It is very important that the dusting be done thoroly. This material is slightly poisonous to man and should be handled accordingly.

INSECTS OF SPECIAL INTEREST TO RETAIL GROCERS

Miscellaneous insects—
- Cockroaches
- Ants
- Lepismids
- Cheese skippers
- Book lice
- Mites

Beetles—
- Confused flour beetles
- Saw-toothed beetles
- Cadelles
- Meal worms
- Broad-horned flour beetles
- Larder beetles
- Red-legged ham beetles
- Drugstore beetles
- Bean weevils
- Pea weevils
- Rice weevils

Moths—
- Mediterranean flour moths
- Indian meal moths
- Meal snout moths
- Angoumois grain moths

INSECT PROBLEMS IN BAKERIES

Injuries Caused by Insects in Bakeries

Insects may injure the business of a baker in two ways: (1) the flour and other raw products may be destroyed, and (2) the reputation of the bakery may suffer because customers find insects in some of the products or see them in the salesroom. In either of these cases

the baker feels a financial loss as well as a loss of time and effort in trying to get rid of the pests.

Fortunately, the destruction of large amounts of flour or their damage beyond the possibility of use, is not very common. However, many such cases are known. For example, in the summer of 1918 a car lot of rye flour was found by the writer to be damaged to such an extent that the baker had to dispose of it for stock feed; and several lots of from 200 to 600 pounds of wheat flour were found in such condition that they were almost total losses. In addition to the actual losses in all these cases, was the necessity for the careful sifting of all flour stored in the same room.

In many cases the loss of the reputation of the bakery is undoubtedly more serious than the loss from flour that has actually been destroyed. This fact was especially emphasized during the war when bakers were having unusual difficulty with the materials that they had to use and when many people were patronizing bakeries to an unusual extent. Many complaints were made by patrons who either had found insects in bread or had seen them in the salesroom. On the other hand, many bakers who realized the seriousness of their trouble appealed for help, in an attempt to avoid the possibility of such complaints.

When a patron finds an insect in the bread he is eating or has seen an insect in the showcase when he is about to make a purchase, no explanation will be accepted and no argument will convince him that there are not insects in all the goods from that bakery. The public is rather suspicious of the places from which its food comes and does not care for apologies with regard to them. There can be no doubt that unfair statements are made on the basis of a single insect found in bread, but the only way to satisfy the public is not to let any insects get into the bakery. An instance of this came to light when a complaint was made that four insects had been found in one loaf of bread and a slice of bread was shown as evidence, but when the bakery was carefully inspected there was no evidence that insects had ever been present in great numbers. It was very evident that the occurrence of these insects in the bread was more or less an accident, but it was a most unfortunate accident because this customer said that he would never trade there again and he also took the trouble to tell his friends about the case.

How Insects Get Into Bakeries

The usual and the easiest way for insects to get into a bakery is for them to be brought in with the flour. Old flour is desirable for baking purposes and the older it is the more opportunity the insects have had to reproduce in it. If the ageing of such flour takes place in the storeroom, the insects may spread to all parts of the bakery.

When exchanged sacks are refilled without cleaning, insects that may be in the sacks have every opportunity to go on reproducing. If sacks from an infested bakery are sent to a clean bakery, the insects will be introduced unless the flour is carefully inspected and rejected. Used sacks should never be refilled without being thoroly cleaned and heated, as will be described later. Flour should never be put in the storeroom until it has been inspected and found to be free from insects.

Conditions That Make It Possible for Insects to Exist in Bakeries

Insects will usually thrive wherever there is sufficient warmth, moisture, and food. The insects with which the baker is concerned develop very slowly at temperatures as low as 55 degrees F.; between this and about 90 degrees the development is rapid, especially at the higher temperatures. Most insects die in a few hours in a temperature of 120 degrees F. and few can endure a temperature of 140 degrees for even a very short time. Thus most of the insects with which we are concerned develop most rapidly, other things being favorable, at a temperature of about 80 degrees F., a temperature either too high or too low is unfavorable for them.

Moisture affects insects in much the same way as does temperature. A medium amount of moisture favors the most rapid growth and development; either more or less is unfavorable for the insects. Unfortunately, the usual moisture content for ordinary flour and meal is favorable for the rapid growth of insect pests. When the moisture content is unusually high, the insects are usually affected more by molds in the flour than by the moisture itself. When it is very low, the material may become too hard for the insects to use as food or the insects may dry up.

Any of the flour and meal used in a bakery are satisfactory food for insects. As the temperature and moisture conditions are usually favorable and as food is always present, a bakery is a good place in which insects can grow and reproduce. From four weeks to a year, depending on the species, are required for insects to pass through all stages from egg to adult, and if careful cleaning is done every day or two the insects can not thrive. This does not mean that an accumulation on the floor of flour less than four weeks old will not contain insects. In warm weather eggs can hatch and good sized larvae ("worms") can develop in a week or ten days; and a stock of flour infested with eggs at the mill may appear to be free from insects one day and be "crawling" with young larvae a few days later.

The most important thing for the baker is not to leave any flour in any place where it can accumulate and remain undisturbed. When even small amounts of flour are left on the floor, they may support enough insects to keep the whole bakery infested.

How to Keep Insects Out of Bakeries

Everything that comes into the bakery should be carefully inspected. Flour containing insects should not be allowed in the place for even the shortest time. Do not keep infested flour for a day or two before sending it back, for the insects may spread to other flour.

Empty sacks should never be stored near the stock of flour. They should be kept in a place by themselves and looked over frequently to make sure that no insects are breeding in them. All sacks in which insects have been seen should be heated in the oven as soon as they have been emptied. Put them not more than three deep on boards and leave them in the oven for five minutes at a temperature of 350 to 450 degrees F. Care must be taken not to let them scorch. The stock of flour should be stored on racks or supports high enough above the floor to make it possible to sweep under it. The storeroom should be dry and cool. The entire establishment should be kept clean, all corners and cracks should be cleaned regularly. Barrels and boxes should never be left unmoved at the time of sweeping.

All mixing and storage bins should be entirely emptied at least once a week and care should be taken to see that no flour remains in cracks and corners. The bins should not have cracks under them or between them and the wall, for such places are ideal for insects to develop in.

All proofing boxes that have cracks in them should be heated in the oven once a week. Any other utensils that may contain insects can be heated in the oven as sacks are heated.

When cockroaches are present, commercial sodium fluoride should be sprinkled about the places where they run. This should be done throughout the whole establishment at the same time. For further details with regard to roaches see page 61.

Ants are difficult to deal with in a bakery. Directions for destroying them are given on page 62.

If insects are already in the stock of flour and in the work rooms, all infested flour should be removed from the regular rooms at once and either fumigated or heated. Directions for fumigation are given on page 72.

It is seldom possible to fumigate the whole bakery, but it may be possible to heat it to a temperature of 120 degrees F. or higher for a few hours. When this is being done, all doors and windows must be tightly closed and boxes and barrels must not be left grouped in corners, as they interfere with the circulation of the air. At least twenty-four hours are required for the center of a sack of flour to come to a temperature of 120 degrees F. when the air surrounding it is at this temperature, therefore it is necessary to keep the heat up for at least that time in order to kill the insects in the flour. The most favorable time for heating a bakery is in the summer, when the outside temperature is high

and when it can be begun on Saturday evening and continued over Sunday. Thermometers should be hung in various parts of the room to make sure that all reach a temperature of at least 120 degrees F. Further directions with regard to heating are given on page 66.

COMMON INSECTS FOUND IN BAKERIES

Miscellaneous insects—	
Cockroaches	Lepismids
Ants	
Beetles—	
Confused flour beetles (very common)	Meal worms (Tenebrio) (not rare)
Saw-toothed beetles (common)	Drugstore beetles
Cadelles (rather common)	Broad-horned beetles
Moths—	
Mediterranean flour moths (common)	Indian meal moths (rather common)
Meal snout moths (rather common)	

INSECT PROBLEMS IN CONNECTION WITH STORED FOOD PRODUCTS IN THE HOME

Losses That Insects Cause to the Housekeeper

The insects with which we are concerned in this bulletin are those that feed upon our food. It is not pleasant to think of eating material that insects have crawled over and from which they have been eating. Most insects have the habit of nibbling a little in one place and then in another so that in eating a very small amount of food a large amount has been injured. Such food is always considered unclean and most people will not eat it if they know of its condition. There is little evidence to show that it may be injurious, but it is safest not to eat it.

The amount of food actually eaten by insects in homes is probably small, but the amount thrown away because insects have been found in it is very large. There is no way of estimating the amount of material lost in this way, but the writer found that about 200 pounds of flour and meal were lost in about a dozen households investigated in one summer. All this loss might have been prevented by proper care in examining the material when it was brought into the home.

Aside from the amount of food lost, a considerable amount of valuable time is required to clean out the cupboards after insects have been discovered in them. Here the old saying will apply: "A stitch in time saves nine." A few minutes spent in examining the groceries will save hours in trying to get rid of the insects. Also a little time spent regularly in cleaning the bins and cupboards will prevent the necessity of special cleaning in order to rid the place of insects.

How Insects Get Into the Home

Insects may come to the home in greater numbers in proportion to the amount of food bought than to business houses from the place of manufacture to the retail grocery. Flour, meal, and cereals move slowly

from the mill to the home and all along the way there are opportunities for the insects to get in. When they once get in they are likely to remain there until they reach the consumer. Eggs that may have got into the material in any stage of its preparation or transportation are usually hatched by the time they reach the home or at least before the food has all been used.

The only advantage that the housekeeper has is that the amount of material bought and kept on hand is usually small and can be carefully inspected and watched. All flour, meal, breakfast food, dried fruits, nuts, and other materials of similar nature should be examined to make sure that they contain no insects. Breakfast foods in sealed packages are usually heated at the time of packing and are usually safe. However, the packages should be examined to make sure that there are no holes in them. Even very small "pin holes" may mean that there are insects in the package. When insects once get into these sealed packages they may destroy a large amount of material without showing any signs on the outside of the package, except for a few tiny holes.

It is not always easy to convince a grocer that material returned several days or a week after it was bought contained insects when it left the store, for there is always a chance that they got into it after it had been taken home. Therefore it is always best to look the material over before it is taken home or at least as soon as it has come into the home.

It must be remembered that insects develop from eggs just as do chickens. It is just as impossible for insects to develop from flour or meal as it is for chickens to develop from chicken feed. Therefore if no insect eggs are allowed to get into the home there can never be any insects there.

Conditions That Make It Possible for Insects to Live in the Home

Wherever there is sufficient warmth, a temperature of between 50 and 100 degrees F., the ordinary amount of moisture, and some food, the insects will live if undisturbed. There are few kitchens and cupboards that do not satisfy these conditions. For this reason all material that comes in must be looked over before it is put on the shelf and everything on the shelf should be gone over several times a year. During the summer, when the temperature is high, insects develop and reproduce much more rapidly than at other times of the year. Therefore special care should be taken at that time.

Sealed packages of breakfast food that are safe on the shelves of the grocery store are opened in the home and are then just as likely to become infested as any other material. Insects are likely to get into small amounts that are sometimes left over and go from them to other food. Any flour left in the bottom of the bin should be cleaned out before the bin is refilled. All cracks and crevices should be care-

fully cleaned and if possible a coat of paint should be applied. Scalding water is a good thing to use when cleaning about the cupboards or storerooms, as it will kill all eggs, even tho invisible.

It is good policy not to have large amounts of flour and cereals on hand at one time in warm weather. Tight tin or glass cans or bins are more easily cleaned than wooden ones and are recommended when it is necessary to keep flour or meal through the summer. Nothing, however, can take the place of cleanliness to prevent insects from living in the home.

COMMON INSECTS ATTACKING STORED FOOD PRODUCTS IN THE HOME

Miscellaneous insects—
- Cockroaches
- Ants
- Lepismids
- Book lice
- Mites

Beetles—
- Confused flour beetles
- Saw-toothed beetles
- Cadelles
- Meal worms
- Larder beetles
- Red-legged ham beetles
- Drugstore beetles
- Spider beetles

Moths—
- Mediterranean flour moths
- Indian meal moths
- Meal snout moths

INSECTS THAT CAUSE DAMAGE TO STORED FOOD PRODUCTS

Beetles and moths or their larval ("worm") stage are responsible for most of the losses to all classes of stored food products. A group of "miscellaneous insects" includes several that at times may be just as destructive as beetles or moths. Among these are mites, which are not insects at all; cheese skippers, which are the larvae of a fly; book lice, ants, cockroaches, and a few others.

On page 34 is a table that will aid in determining to what group any given insect belongs. No attempt is made to include every species or to give a complete description of any of the insects included, but it will help one without a technical knowledge of insects to determine for himself what one he has found.

It should be kept in mind that insects that attack unmilled grains are, in general, quite distinct from those that attack milled products. One general exception is that insects that attack unmilled wheat will also attack macaroni, spaghetti, hard biscuits, and other hard products that in consistency resemble the wheat berry more than flour or meal. As a result, when flour is stored near wheat that is infested with weevil, a few weevils may enter the flour, but they can not reproduce in it, hence they will cause little damage. But if macaroni is stored near the infested wheat, it will be seriously damaged. If wheat or macaroni is stored near flour that is infested with flour beetles, there

is little danger of the wheat being injured, for flour beetles have difficulty in attacking sound wheat. If the wheat has first been injured by weevils, it will consist of hollow berries that the flour beetles can attack in the same way that they attack flour or meal. There is a great deal of literature describing the insects that attack stored food products and telling of their habits. Some of the more available publications are listed below. Others, which deal with certain species, are listed at the end of the descriptions of those species.

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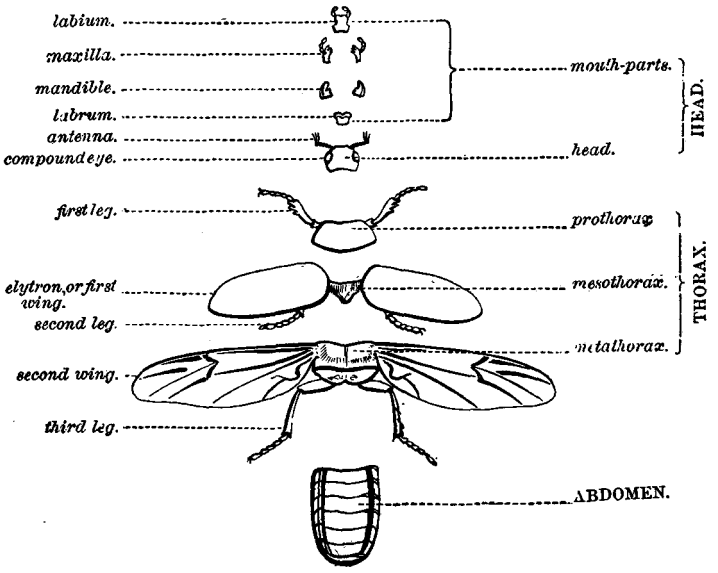


Fig. 2. Body of Adult Beetle Separated to Show Parts

Structure of a Typical Insect

In order to understand the descriptions of the insects it is necessary to know the general structure of an insect. As indicated in the accompanying drawing, the body of both the larva and the adult is divided into the head, thorax, and abdomen. The head bears the antennae (or feelers), the eyes, and the mouth parts. The thorax has three sub-

divisions each bearing a pair of legs and in the adult the last two subdivisions each bear a pair of wings. In beetles the first pair of wings, the elytra, are hardened, forming a cover for the hind wings, which are folded underneath when at rest. In moths both pairs of wings are covered with dustlike scales. The abdomen of the adult has no appendages.

The larva has no wings and the abdomen is usually much longer than that of the adult. The thorax usually so much resembles the abdomen that it can be distinguished only by the legs. The larvae of moths usually have fleshy legs on the abdomen. These are called prolegs to distinguish them from the true legs, which are found on the thorax. As larvae grow from the time they hatch until they are ready to transform to adults, it is not possible to give measurements that will be of any value in determining the species to which they belong. The larvae of some of the larger beetles become so much larger than those of the smaller beetles that they can easily be distinguished during the last part of their development, but when they are newly hatched they are small like the others.

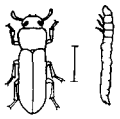
Life History of a Typical Insect as Found in Stored Food Products

All insects hatch from eggs with the exception of a few that are born alive. A typical life history is that of the confused flour beetle. All stages of its life are illustrated on page 51. The eggs, which are only about one-fiftieth of an inch long or less, hatch in about ten days under summer conditions. The larvae or "worms" are very small when they first emerge from the eggs. As they eat and grow they shed their skins periodically and their heads are larger after each successive molt. (See Figures 3 and 4 of Plate I.) When they have reached their full size they feed for a time and again molt their skins. At this time they are changed from larvae to pupae (Fig. 6). The pupa is inactive. It does not move about or feed. The purpose of this stage is to transform the larva to an adult beetle. It usually lasts about ten days, depending upon temperature and other conditions. During the last days of the pupal stage the adult organs can be seen through the thin skin which is to be molted when the adult emerges. The larvae of most moths and of a few beetles form a cell or cocoon in which the pupal stage is spent.

The adult insects mate and lay eggs but they never grow. All the growing is done in the larval stage. Adult beetles feed and may live for a year, during which time they crawl or fly about. Adult moths feed very little, if any, and live for only a few days or weeks. Thus the life cycle of these insects consists of four stages: adults, eggs, larvae, and pupae. With this in mind no one should ever believe any of the stories with regard to insects developing from the germ of the wheat or from anything except insect eggs.

TABLE FOR DETERMINING THE SPECIES OF INSECTS

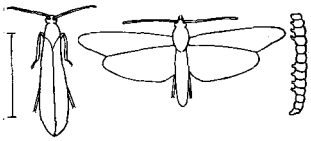
(The actual size of each insect is shown by the line in the drawing.)



I Beetles (*Coleoptera*)

Adult—Hard external covering, wing covers meet in a straight line down back.

Larvae—"Worms" with six legs—do not spin silk. See page 35.



II Moths (*Lepidoptera*)

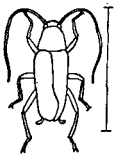
Adult—Four wings covered with dust-like scales.

Larvae—"Worms" with more than six legs—usually sixteen. Spin silk. See page 37.

III Miscellaneous Insects

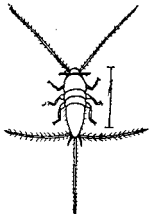
(All not included above.)

They are distinguished as follows:



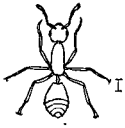
Cockroaches, see page 61.

a. Leathery wings, long legs, and feelers (antennae). Active runners.



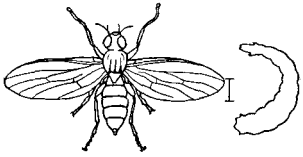
Silverfish (*Lepisma*), see page 61.

b. No wings. Covered with dust-like scales. Active runners. Three "tails" at end of body.



Ants, see page 62.

c. No wings, hard external covering, feelers (antennae) shorter than legs. Live in colonies.

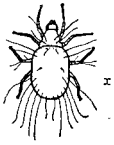


Cheese Skippers, see page 63.

d. Adults fly about, small, have only two wings. Larvae, maggots in cheese and dried meat. Jump about by curving and extending the body.

Book Lice, see page 63.

e. No wings, small, flat, active. Long feelers (antennae), large heads. Found in flour, seeds, book binding, etc.

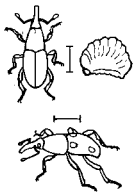


Mites, see page 64.

f. Very small, soft, rather inactive. Eight legs. Large numbers give sweetish odor.

BEETLES (*Coleoptera*)

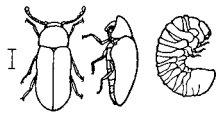
I. Adult beetles with long snouts. Larvae legless grubs inside of grains or other hard material. (For all other beetles see II.)

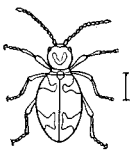


A. Adult—Red or blackish beetle without spots. Found in wheat, barley, corn, macaroni, or other hard products. Granary weevil, *Sitophilus granaria,* see page 38.

B. Adult—Red or blackish beetle with four more or less obscure light spots on the back. Habits like those of the granary weevil. Rice weevil, *Sitophilus oryzae,* see page 39.

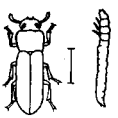
II. Adult beetles without long snouts. Larvae with legs. (For all beetles with long snouts see I.)





A. Adults—Reddish brown.

1. Adult—Half as broad as long. (For all other reddish brown beetles see 2.)
   a. Adult—Minute lines down back.
      Larvae—Grubs with few short hairs.
      Drugstore beetle—*Sitodrepa panicea,* see page 40.
   b. Adult—No lines on back.
      Larvae—Grubs covered with long hair.
      Cigarette Beetle—*Lasioderma serricorne,* see page 41.
   c. Adult—Spider-like with indistinct patches of white on back.
      Larvae—White grubs in cases. Found in a wide variety of substances. White-marked spider beetle, *Ptinus fur,* see page 41.



2. Adult—Less than half as broad as long. (For all other reddish brown beetles see 1.)
   Larvae all much alike.
   a. Adult—Mandibles projecting out in front like large horns. Broad-horned flour beetle, *Gnathocerus cornutus,* see page 53. Found in flour, meal, and other cereal products.
   b. Adult—Flat, no "horns," gives off a pungent odor when crushed between the fingers. Confused flour beetle, *Tribolium confusum,* see page 48.
   c. Adult—Very small flour beetles. Small eyed flour beetle, *Palorus ratzeburgi,* see page 54.
   d. Adult—Long, slender, "teeth" on sides of the thorax. Saw-toothed grain beetle, *Orizaephilus surinamensis,* see page 50.

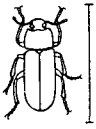
e. Adult—Thorax straight sided, about as broad as the abdomen, no "teeth" on sides of thorax. *Silvanus gemellatus,* see page 42.

f. Adult—Robust, antennae enlarged at end, thorax with nob on front angles. Foreign grain beetle, *Cathartus advena,* see page 42.

g. Adult—Small and slender. Antennae long and slender. Flat grain beetle, *Laemophlaeus pusillus,* see page 42.

B. Adults—Black, gray, bluish, or varied colors, never reddish brown. (For all reddish brown beetles without snouts see A.)

1. Large black beetles more than one-fourth of an inch long. Larvae white or yellowish, attaining a length of half an inch or longer.



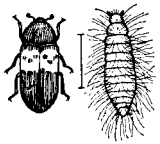
a. Adult—Beetle one-half inch long. Larvae yellow, round, may become one and one-half inches long.
Meal worm, *Tenebrio molitor,* see page 47.

b. Adult—Beetle a little more than one-fourth inch long, Cadelle, *Tenebroides mauritanicus,* see page 45.

2. Small beetles, less than one-fourth inch long, color black, bluish, gray, or varied.
(For all black beetles over one-fourth inch long see 1.)

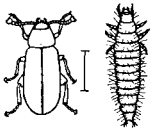
a. Adults—Plump gray beetles found in peas and beans.
(1) With small but distinct white spots—in peas, Pea weevil, *Mylabris pisorum,* see page 45.

(2) Without distinct white spots—in beans. Bean weevil, *Mylabris obtectus,* see page 43.

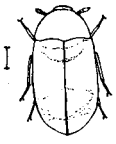


b. Adult—Black or dark brown or bluish or vari-colored beetles.

(1) Adult—Dark brown or black with a light band across the middle of its body. Larva covered with long hairs. Larder beetle, *Dermestes lardarius,* see page 54.

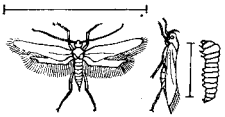


(2) Adult—Steel-blue, legs reddish, one-fifth of an inch long. Larva white with brown head. In cured meat. Red-legged ham beetle, *Necrobia rufipes,* see page 55.

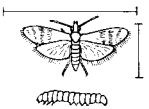


(3) Adult—Small black beetle spotted with gray and light brown. Larvae with long hairs at the posterior end. Large cabinet beetle, *Trogoderma tarsalis,* see page 55.

MOTHS (*Lepidoptera*)

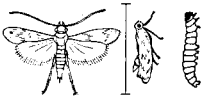


I. Adult—Narrow pointed wings fringed with hair. Larvae found inside of kernels of corn, wheat, etc. Emerge as adults through small round holes. Angoumois grain moth, *Sitotroga cerealella,* see page 57.



II. Adult—Inner half of front wings, light brown, outer half dark. Larva—yellowish, green, or pink in color—living free—not in silk tube.
Indian meal moth, *Plodia interpunctella,* see page 57.

III. Adult—Base and outer portion of front wings brownish red, middle portion whitish.
Larvae solid grayish, darker at ends, found webbing the food substances together, living within a silken tube in moist chaff or vegetable debris. Meal snout moth, *Pyralis farinalis,* see page 58.



IV. Adult—Dark grayish with blackish streaks across the wings resembling the letter "V" or "W."
Larvae yellowish white or pinkish, often with a dark spot near the middle of the body. Found in flour and feed.
Mediterranean flour moth, *Ephestia kühniella,* see page 59.

DESCRIPTIONS OF THE INSECTS

GRANARY WEEVIL (*Sitophilus granaria* Linn.)

The granary weevil is a true weevil or snout beetle. It is far more common farther south than in Minnesota. Its importance in the far north is due to the fact that it is continually shipped in with southern wheat. Certain seasons are exceptional and spring wheat in Minnesota may be badly infested. This condition probably is due to a mild winter.

The adult is a shiny reddish brown beetle about one-sixth of an inch in length, and with a long "snout" or proboscis. The females make small holes in the wheat kernel in which the eggs are laid. The larvae hatch and spend their lives within the kernels as legless grubs, eating out the interior of the kernel, which is a mere shell when they reach maturity. The adult beetles as well as the larvae feed on the wheat, or on corn, oats, barley, or rye. Macaroni and other hard products, such as pearled barley, are also infested by the beetle. However, they can not survive and reproduce in milled products. The adults may feed upon such material for a short time but the larvae require hard masses of food at least as large as a wheat kernel for the completion of their development. Adults may live a month or two without food, depending upon the temperature, and for 7 or 8 months under normal food conditions.

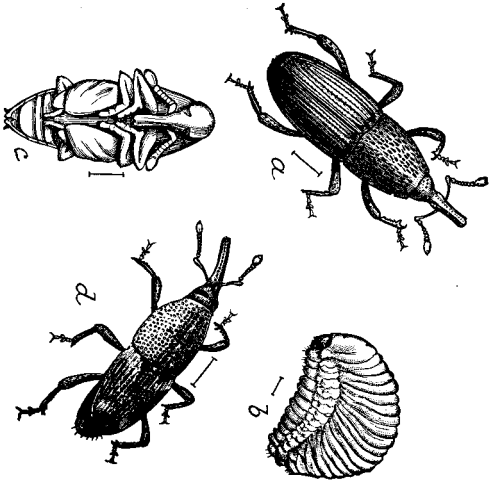


Fig. 3. Granary Weevil, *Sitophilus granaria*
a, adult; b, larva; c, pupa; d, *Sitophilus oryza*, adult (From Chittenden)

Experiments have shown that no stages of the granary weevil survive the process of milling semolina for macaroni even tho the wheat is very heavily infested. Adult weevils do not lay eggs in the semolina even tho left in it until they die. If semolina is re-infested with adult

weevils or with various stages of flour beetles, macaroni made from it contains no living insects or eggs as it comes from the press. Hence infestation of macaroni by weevils is due to introduction of the insects after the product has left the presses.

The methods of controlling this pest are given on page 72.

See literature on *Sitophilus oryzae*.

Rice Weevil (*Sitophilus oryzae* Linn.)

The adult rice weevil is a dull reddish brown and so resembles the granary weevil in appearance and habits that it may often be confused with it. It is primarily a pest of the Gulf and South Atlantic states but is introduced into the north in shipments of rice and wheat.

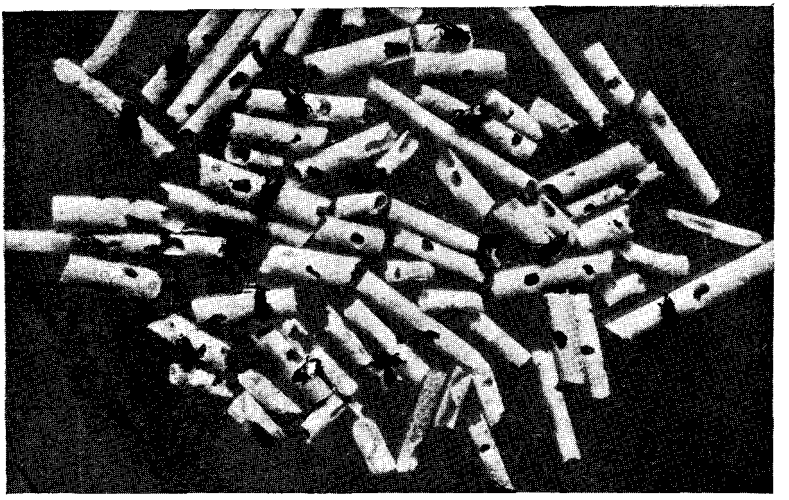


Fig. 4. Granary Weevil and Its Work in Spaghetti. Slightly enlarged

The rice weevil may usually be distinguished from the granary weevil by four light spots on the wings. In its life history it differs from the granary weevil in having functional wings, and that in the south the female may lay her eggs on standing grain or in the shocks or stacks in the field. Otherwise the life histories are very similar.

This weevil attacks rice, wheat, oats, corn, barley, sorghum, buckwheat, kafir, macaroni, and other hard products. It has also been reported as attacking caked flour and meal which was hard enough to afford a favorable environment for the larvae.

Control methods are described on page 72.

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Cotton, R. T. Rice weevil (*Calandra*) *Sitophilus oryza*. Jour. of Agr. Res. 20:409-422. 1920.
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Chapman, R. N. The possibility of transmitting a Calendra infestation from wheat to macaroni through the processes of milling and manufacturing. Jour. Econ. Ent. 16:341-348. 1923.
Back, E. A. and Cotton, R. T. Relative resistance of the rice weevil (*Sitophilus oryzae*) and the granary weevil (*S. granarius*) to high and low temperatures. Jour. Agr. Res. 28:1043-1044. 1924.
Back, E. A. and Cotton, R. T. The granary weevil. U. S. Dept. of Agr. Bull. 1393. 1926.
Robinson, Wm. Low temperature and moisture as factors in the ecology of the rice weevil, *Sitophilus oryzae* L., and the granary weevil, *Sitophilus granarius* L. Minn. Tech. Bull. 41. 1926.

Drugstore Beetle (*Sitodrepa panicea* Linn.)

Because of its ability to attack a large variety of foods, this beetle is one of the most injurious and hardest to combat of all insects in stored food products.

The adult beetle is about one-tenth of an inch in length and reddish brown in color. The antennae end in three large joints that form a sort of club. It is not to be mistaken for the confused flour beetle, as it is shorter and broader in proportion.

The larvae are small white grubs covered with silky hair and have three pairs of small legs. The end of the abdomen is usually bent under the body, giving the larva an arcuate appearance.

The life cycle requires about two months during warm weather. The larvae combine the characteristics of "grubs" that work within hard products, as kernels of grain, and of those that crawl about in milled products. They are usually found within grains, macaroni, or other food material and the pupae are either in the larval burrows or in cases formed by fastening food particles together. The adults feed on the same food as the larvae.

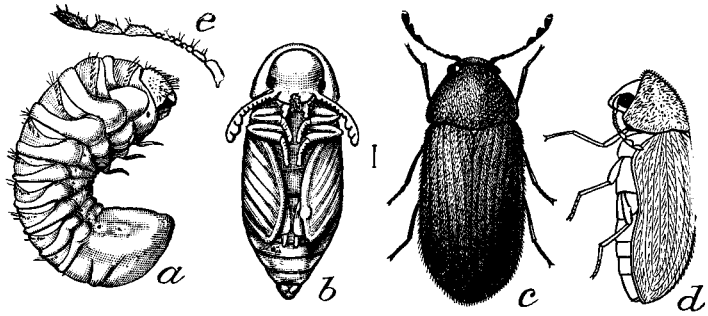

Fig. 5. Drugstore Beetle, *Sitodrepa panicea*
a, larva; b, pupa; c, adult, dorsal view; d, lateral view; e, antenna (From Chittenden)

Apparently almost any organic material may serve as food for the drugstore beetle. The list of the foods that it has been known to attack includes more than a hundred items, among them grains and grain products, drugs, peppers, spices, and other plant products. When it

once infests a warehouse, practically everything in the place must be examined, for a few beetles may escape in some unthought-of material.

REFERENCES

Blaisdell, F. E. List of drugs found infested by *Sitodrepa panicea*. Insect Life, 5:33. 1892.
Chittenden, F. H. The drugstore beetle and its allies. U. S. Dept. of Agr. Bur. Ent. Bull. 4. 124 pp. 1896.

CIGARETTE BEETLE (*Lasioderma serricorne* Fabr.)

The cigarette, or tobacco, beetle resembles the drugstore beetle in appearance and habits.

The adult is only about one-sixteenth of an inch long and is covered with fine hairs. It differs from the drugstore beetle in that the last three joints of the antennae are about the same size as the others, and the head is bent not quite so far under the body. The larva resembles that of the drugstore beetle, but it is very hairy, the end of the body is bent under to a much less degree, and the head is very differently marked.

While this beetle is primarily a pest in tobacco, it infests many food products and has even been reported as destroying silk upholstering on furniture. Spices and cayenne pepper are often infested by it. As the "tow bug" it is often reported occurring in overstuffed furniture that contains flax tow.

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Runner, G. A. The tobacco beetle, an important pest in tobacco products. U. S. Dept. of Agr. Bull. 737. pp. 1-77. 1919.
Back, E. A. and Cotton, R. T. Tobacco beetle as a pest of furniture. Furniture Manufacturer, Dec. 1927.

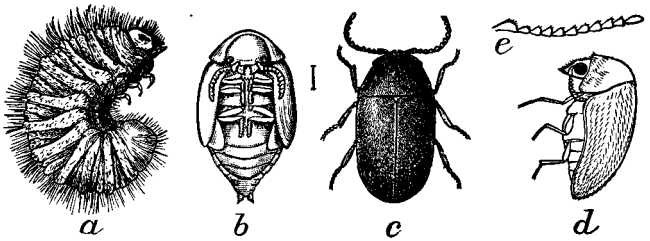

Fig. 6. Cigarette Beetle, *Lasioderma serricorne*
a, larva; b, pupa; c and d, adult (From Chittenden)

WHITE-MARKED SPIDER BEETLE (*Ptinus fur* Linn.)

The six rather long legs and the equally long antennae of this oval bodied beetle give it the appearance of a spider. The beetle is about one-eighth of an inch long and the general color is brown with blotches of yellowish white hairs on each side of the body. The larvae are white grubs, which are usually found in cases made of the food material

cemented together. Its entire life cycle may be passed in a little less than four months under favorable conditions.

This is a rather serious pest for it can live in such a wide variety of materials. It is reported as attacking flour, meal, various groceries, bookbinding, clothing, and paper. In one case it is said to have made a continuous tunnel through seven volumes of books through which a string could be passed. Cases are reported in which it has completely over-run general stores.

For the last few years there have been cases of infestation by this beetle that have already caused rather serious losses and that are still likely to do considerable damage if they get started in some of the general stores of the country districts.

The ability of this insect to attack a variety of substances makes it necessary to combat it vigorously. Fumigation or heat, and careful cleaning must be resorted to.

Square-Necked Grain Beetle (*Silvanus gemellatus* Duv.)

This is one of the smaller beetles, which is less abundant in the north than in the south. The adult is very small, slender, flat, and reddish brown in color. The rectangular thorax with its smooth straight sides is quite characteristic.

In Minnesota this is one of the less common beetles, found in accumulations of small grains and occasionally in dried fruits. When temperatures are high the entire life cycle requires only a little more than three weeks for completion.

Foreign Grain Beetle (*Cathartus advena* Waltl.)

A small beetle which is found primarily in moldy grain or milled material.

The adult is reddish brown, about one-tenth of an inch long and much broader in proportion to its length than any of the other beetles except the drugstore beetle. It can be distinguished from the latter by the horizontal head and the barrel-shaped thorax.

In breeding experiments reported by Dr. F. H. Chittenden, it was found that these beetles could not breed on fresh grain but thrived on moldy grain. Thus these beetles are not a pest in clean, dry places. Damp oats may be infested with this insect and in some cases a considerable amount of damage is done.

Flat Grain Beetle (*Laemophlaeus pusillus* Schön.)

This very small beetle is not common and has been found principally in cracks and crevices of flour bins and mills.

The adult is about one-tenth of an inch long, is flat, narrow, and reddish brown in color. Its long slender antennae together with the narrowing of the thorax near the posterior end will characterize it.

This beetle apparently lives in undisturbed places where fungi are present. It has not been found commonly in sound grain, despite its common name, but rather in flour or meal and in soft, moldy grain.

BEAN WEEVIL (*Mylabris obtectus* Say) (*Bruchus* of authors)

The bean weevil is the cause of a great amount of damage to beans in storage. Any case of "buggy" beans is quite sure to be a case of bean weevil.

The adults vary greatly in size, averaging about one-eighth of an inch in length. The wing covers are mottled with light and dark spots. The larvae are legless grubs.

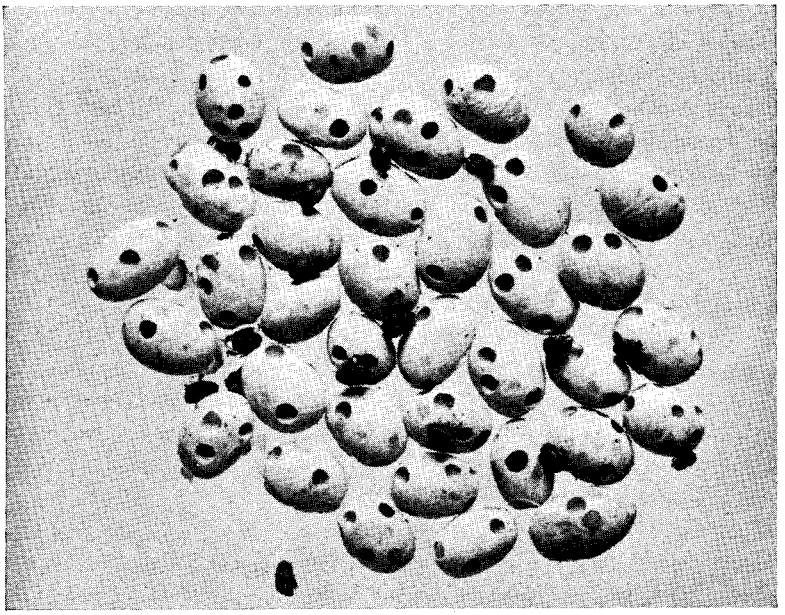

Fig. 7. Beans Infested with Bean Weevil, *Mylabris obtectus*

The eggs may be laid in the pod in the field. The larvae burrow into the beans and eat out a cavity. When mature they form a cell near the surface and transform within it. A small round spot can be seen on the bean after this cell has been formed. When the adult is ready to emerge it removes a portion of the outer coat of the bean, leaving a circular opening through which it emerges.

If the temperature is high, the life cycle may be shortened to about thirty days. The pest is made more serious by the fact that it continues to breed while the beans are in storage. The adults will emerge throughout the winter, if the temperature is high enough, and lay their eggs. Thus they multiply throughout the year and if not checked will destroy the beans.

Prevention

The best preventive measure is to plant beans that are free from all weevils. The seed should be carefully inspected, for if weevils are present they will emerge in the field and the new crop will be infested. If the seed is clean and there are no infested beans growing near, the crop will be free from weevils.

If the beans are infested, the weevils should be killed at once. This may be done by fumigating with a gas or by heating the beans. For small amounts of beans that can be conveniently placed in the oven, heating is the more convenient method. For larger quantities the use of gas is more convenient.

Heat method.—While heat will kill weevils it will not remove them from the beans. Therefore it is well to separate the infested beans from the uninfested before heating. This can be done by putting the beans in water. The badly infested beans will float and can be skimmed off and thrown away. Those that sink are either not infested or they contain very few larvae, and should be taken out of the water and put in shallow pans for heating.

General directions for heating are to be found on page 66. As heat penetrates beans very slowly, it is well to have them not more than an inch and a half or two inches deep in the pans. If they are to be used for seed, care must be taken to avoid injury to the germ, which will occur at about 170 degrees F.

Gas method.—See page 72.

Storing.—If beans are stored over winter where the temperature is less than 40 degrees F., weevils will not develop even if they are present. If beans or peas are stored in heavy cotton sacks rather than loosely woven bags, weevils can not spread from infested lots to uninfested ones.

Air-slaked lime is recommended by some as a means of preventing the weevils from developing in beans. The lime and the beans are put in bins together, the lime filling in the spaces between the beans. For this purpose one part by weight of lime is used for every two parts by weight of beans. When small quantities of beans are stored the proportion of lime should be greater.

For literature, see following the pea weevil.

PEA WEEVIL (*Mylabris pisorum* Linn.) (*Bruchus* of authors)

The pea weevil resembles the bean weevil in general appearance but is slightly larger and has more conspicuous markings on the wing covers. The adult beetle is about one-fifth of an inch in length.

The general description of the life history of the bean weevil will apply here with one important exception. This species can not pass through its life cycle while the peas are in storage and the cycle requires a year for completion. The eggs are laid on the pod in the field and the larvae enter the green peas. If the peas are put into storage for seed, the development is completed and the adult normally emerges the next spring. However, if peas are exposed to a high temperature they emerge a little earlier. If the peas are infested they may be kept in storage through the second winter with the result that all adult beetles will die and leave no progeny, for the larvae can not enter the hard peas. Care should be taken to prevent any adult beetles from escaping to the pea fields to lay their eggs.

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CADELLE (*Tenebroides mauritanicus* Linn.)

The adult is a shiny black beetle about one-third of an inch long. It has a constriction between the head and the thorax that distinguishes it from the adult of the "meal worm" (*Tenebrio*). The larvae are about three-fourth of an inch long when fully grown and are much broader and softer than the other beetles found in stored food products. They are of a dirty white color except for the black head and dark brown spots on the thorax and two brown spines on the end of the body. The pupa is found in a cell formed of flour or other material and is soft and white, with an old larval skin clinging to the end of its body.

Life History and Habits

There has been some disagreement as to whether this beetle should be considered a "grain," a "flour," or a "meal" beetle. Inspection of storage places has shown that it is usually found in ground cereal products. It can attack unground grains, as wheat and oats, and usually

confines itself to the embryo, which shows that it can not eat more than a small portion of unground grain, the embryo being all that is soft enough. However, when seed grain has been attacked it is just as completely ruined as if it had been consumed.

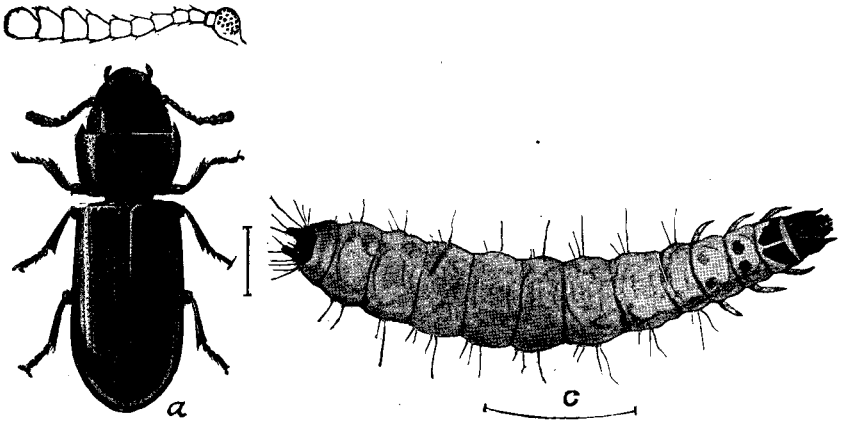

Fig. 8. Cadelle, *Tenebroides mauritanicus*
a, adult with greatly enlarged antenna above and c, larva (From Chittenden)

It has been said that the cadelle is beneficial to a certain extent, in that it attacks and destroys other grain insects. Experiments have shown that under ordinary conditions this is more due to chance than anything else and that it does not make any special effort to devour other insects. When feeding in grain, where their food is limited, they will readily eat other insects.

The larvae are very troublesome because of their habit of eating holes in paper sacks and other food containers. As they are among the largest of the insects that infest stored food products, the holes make it possible for practically all other insects to enter the packages in which these beetles have eaten holes. They may burrow into wood adjoining grain in bins, pupating or hibernating there, possibly for months while the bin is empty, coming out to infest a fresh lot of grain placed in the bin.

This beetle, like the "meal worm," requires a year for complete development from the egg to the adult, which is ready to lay eggs again. This is a distinct advantage to all who are trying to keep their storage places clean. If the place is thoroly cleaned several times each season there is little chance that any of the larvae will survive.

These beetles are often found in large numbers in warehouses, which means either that regular cleaning is not being done, or that goods are being held in storage for longer periods than is necessary.

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YELLOW MEALWORM (*Tenebrio molitor* Linn.)

DARK MEALWORM (*T. obscurus* Fab.)

These two beetles are so much alike in both habits and the nature of the damage they do that they will be treated together.

The adult beetles are black and a little more than half an inch long. They are more easily confused with the cadelle than with any of the other insects found in stored food products, but can be distinguished by the fact that the sides of the body are continuous in both these beetles, while there is a constriction in the body of the cadelle.

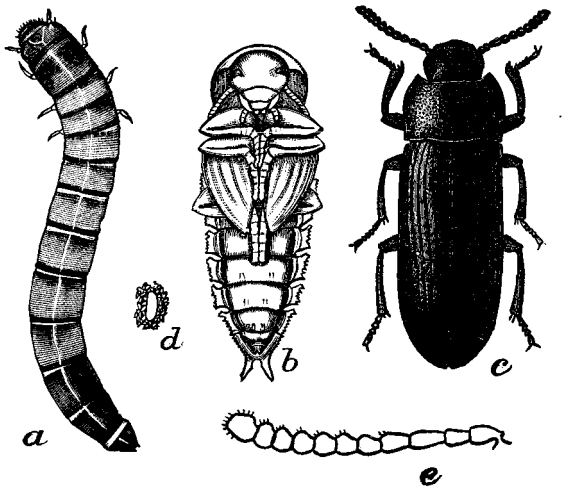

Fig. 9. "Meal Worm," *Tenebrio molitor*
a, larva; b, pupa; c, adult female; d, egg with case; e, antenna (From Chittenden)

The larvae are long, yellow or dark brown in color, with a hard external covering that makes them resemble "wire worms" in appearance. When fully grown the larvae are more than an inch long and are hardly to be confused with any other insects found in stored food products.

Life History and Habits

These beetles are found primarily in rather coarsely ground cereals. They also have a preference for damp and slightly moldy material. For this reason they are usually found in accumulations of meal in dark, damp, out-of-the-way places such as under granaries, elevators, and warehouses.

The adults usually emerge in the spring and lay eggs in the material that is to serve as food for the young larvae. When the larvae hatch they are white but later become yellowish brown in color, in case of the "yellow meal worm"; or dark brown in case of the "dark meal worm." The larvae attain their full length, an inch or more, by the middle or latter part of summer, but they usually remain in this condition until the following spring, when they transform to the pupal stage.

The larvae usually come to the surface of the meal to pupate and the white pupae are found on the surface of the food or in corners of the bin. The adults emerge from the pupal stage, and, owing to their nocturnal habits, feed at night or in dark and secluded places.

It is evident from the life history and habits of these beetles that one way to keep a place free from them is to have no accumulations of cereals lying about in secluded places where it may become damp and moldy. As the life cycle requires a full year for completion, it is further evident that careful and frequent cleaning will keep a place free from these pests.

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Black Fungus Beetle (*Alphitobius piceus* Oliv.)

This beetle resembies the mealworm adults in form and color but is considerably smaller. It is proportionately broader. The eyes are divided so that they appear to lie one pair on the upper and one on the lower surface of the head. It is found in similar locations as mealworms, especially in dark damp corners beneath machinery and under grain or flour sacks.

Confused Flour Beetle (*Tribolium confusum* Duval)

Red Rust Flour Beetle (*Tribolium ferrugineum* Fab.)

These two beetles are so much alike both in appearance and in habits that the average person will not distinguish between them. They are the beetles most commonly found in flour. The confused flour beetle is the one commonly found in Minnesota. It is dark reddish brown about one-sixth of an inch in length and flattened and oval in outline. It crawls about slowly. When rubbed between the fingers it gives off a rather sharp pungent odor which irritates the membranes of the nose. The common "flour worms" are its larvae.

The larvae vary in length from about one twenty-fifth of an inch, at the time of hatching, to about one-fourth of an inch when full

grown. Their color varies from white, for a short time after each molt, to yellow. This is the color usually seen. The covering of these larvae is not so hard as that of the "meal worms" (*Tenebrio sp.*) nor so soft as that of the cadelle (*Tenebroides*). As they are smaller than the two species just mentioned, and are usually associated with the adult beetles, they can usually be distinguished from other beetles commonly found in cereal products.

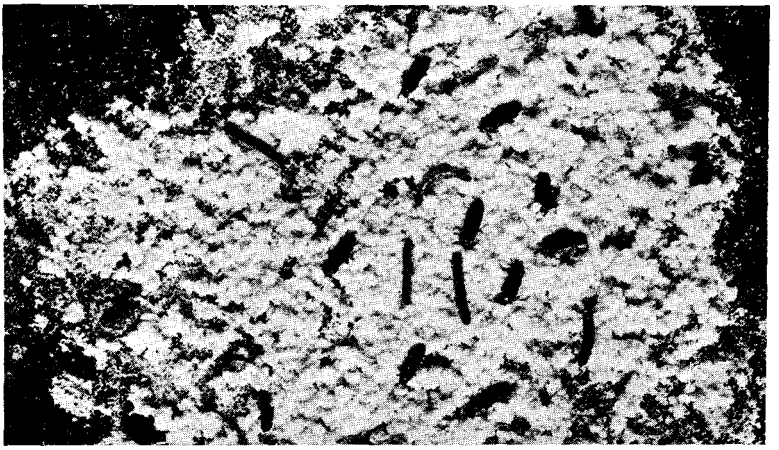

Fig. 10. Flour Containing Adults, Larvae, and Pupae of Confused Flour Beetle

The pupae are seen less often than the other stages just described, because they are inactive. They are white and about one-sixth of an inch long. (See Fig. 6, Plate I.)

The eggs are so small that they are scarcely distinguishable with the unaided eye even in the finest flour. They are only about one seventy-fifth of an inch long and are oval. When first laid they are covered with a fluid which causes particles of flour to adhere to them, with the result that the appearance of the eggs varies with the character of the material in which it is laid. The eggs are laid singly and are scattered about in the flour or attached to the sides of sacks or bins. The female beetle may live for nearly a year and lay one or two eggs every day during this time.

Life history of the confused flour beetle.—At a temperature of 80 degrees F. the eggs hatch in about a week. The growth of the larvae is rapid in favorable food, and practically any flour or cereal used for human food is favorable food for these insects. The larvae often mature in twenty-two days at a temperature of 80 degrees F. The pupal stage lasts ten days under these conditions, making the total time from the egg to the adult about forty days. The adult beetles have been

known to live for about a year under favorable conditions in the laboratory.

The confused flour beetle feeds on nearly all grain and vegetable products, primarily on the ground products of grains. It can not attack uninjured grain. However, it is often found in wheat that has been crushed or injured by other insects. It may be found in small numbers in sound grain and also in other materials that are not suitable for food, but experiments have shown that it can not obtain food from such sources, and soon dies.

It has often been said that these beetles show a preference for the lower grades of flour, but there seems to be no marked preference. Experiments have not yet determined what governs these beetles in their choice of food. The lower grades of flour may become infested more often than the higher grades, because they are not sifted through such fine bolting cloth and are not handled with the same care.

The confused flour beetle has been found in wheat, barley, oat, rye, corn, and rice flour; bran; breakfast foods; grains ground or rolled in various ways; corn starch, peanuts, beans, peas, baking-powder, orris root, ginger, cayenne pepper, and snuff. This does not mean that they feed on all of them, but the presence of the beetles injures the value of the material.

These beetles may be killed by a temperature of 120 degrees F., or by the use of a poisonous gas. During the process of fumigation the beetles often crawl away into cracks, and hence are not so easily reached with fumigation as with high temperature. They have a natural enemy in a small mite that feeds on the eggs, the young larvae, the pupae, and the adult beetles. Apparently all the eggs attacked are killed, but their effect on the other stages is less noticeable.

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Saw-Toothed Grain Beetle (*Orizaephilus surinamensis* Linn.)

The adult saw-toothed beetle is slender, brown, and smaller than *Tribolium*, being only about one-tenth of an inch in length. The sides of the thorax bear six tooth-like projections from which it gets its common name. This is one of the most common beetles occurring in flour, cereal products, and many other foods. The larvae are smaller than those of the confused flour beetle, which they resemble.

Figure 11 shows the larva, pupa, and adult. As can be seen, the thorax of the adult and pupa will serve to distinguish them from all

Fig.1

Fig.2

Fig 3

Fig 5

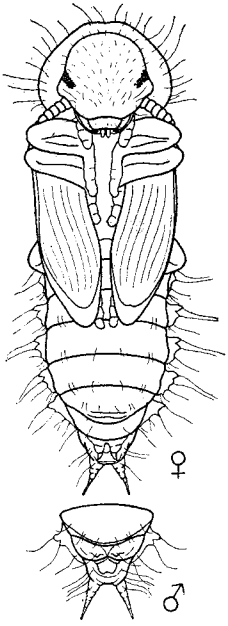
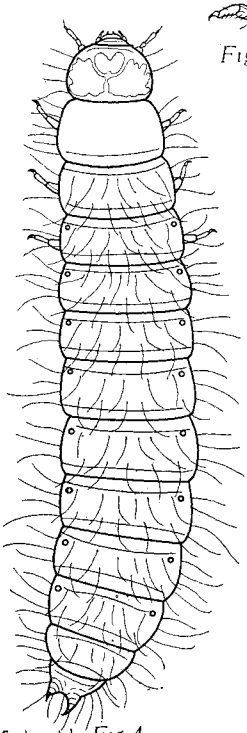


Fig.6



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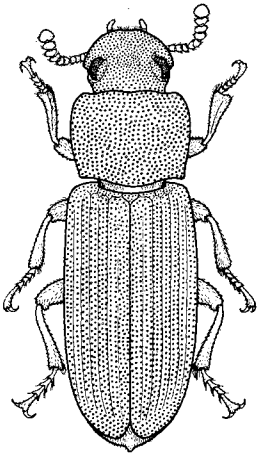

Fig.7

Plate I. Life History of *Tribolium confusum*

other beetles. The larva is more difficult to distinguish from those of other species. Its great activity and the large relative size of the legs and the antennae will be the best guide, together with the species of adult beetles associated with it.

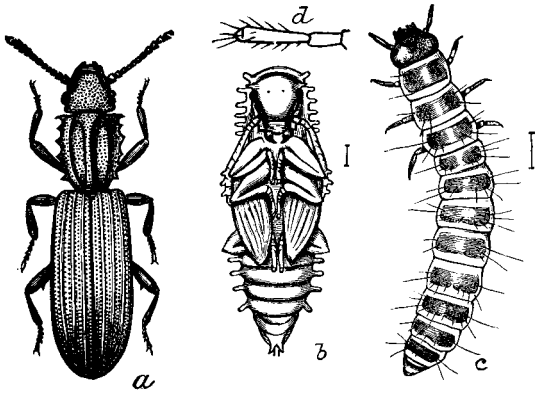

Fig. 11. Saw-Toothed Grain Beetle, *Orizaephilus surinamensis* a, adult; b, pupa; c, larva; (From U S. Dept. of Agr.)

Life history of the saw-toothed grain beetle.—The saw-toothed beetle is reported as feeding upon various grains, meals, breakfast foods, flour, starch, dried meats, dried fruits, sugar, spices, tobacco, and other materials. Its name is misleading, it is not a true grain beetle but one that feeds on ground products. However, it may be found in various substances when other food is not available. It is sometimes a pest in damp grains, especially oats.

The eggs are long. They hatch in about a week after they are deposited if the temperature is about 80 degrees F. The larvae are long and active and crawl about as they feed. In about three weeks, in warm weather, they attain their full size and form cells by sticking particles of material together with a substance that they secrete. Often they crawl into a crack and surround themselves by particles of food glued together to complete these cells. In the cell the pupal stage of about ten days is spent, then the adult emerges. The whole life cycle, from egg to adult, may require from three to ten weeks, depending upon moisture and temperature.

Both adults and larvae make holes in sacks and boxes that contain their food. These holes are smaller than those made by the cadelle but are, nevertheless, annoying. They are said to have made holes through aluminum can covers, but such reports have never been substantiated.

The small size of this beetle makes it possible for it to crawl into small cracks and crevices and escape efforts to get rid of it by cleaning.

The methods to be used against it are similar to those recommended for the confused flour beetle.

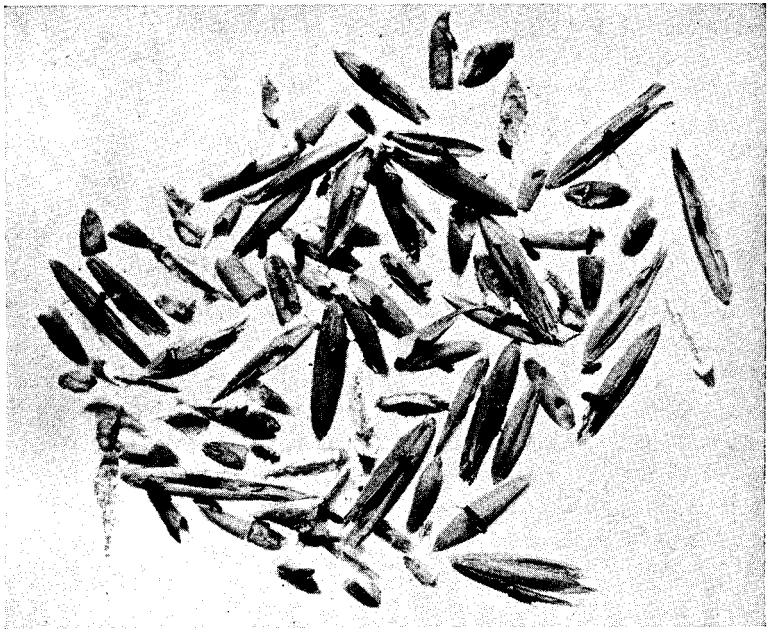

Fig. 12. "Bran Bugs," Saw-Toothed Grain Beetle, Foreign Grain Beetle, and Flat Grain Beetle in Moist Oats (slightly enlarged)

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Broad-Horned Flour Beetle (*Gnathocerus cornutus* Fab.)

Slender-Horned Flour Beetle (*Gnathocerus maxillosus* Fab.)

These beetles are much alike in structure and habits. The adult beetles are reddish brown in color and about one-eighth of an inch long. They may be distinguished from other beetles by the long jaws, which project out in front between the antenna-like horns. The broad-horned species differs from the slender-horned in the width of the jaws.

These beetles resemble the confused flour beetle in habits but their occurrence is much rarer. They often occur with the confused flour beetle, sometimes in large numbers. Their larval development takes place in about four months and the adult beetles live about ten months.

SMALL-EYED FLOUR BEETLE (*Palorus ratzeburgi* Wissm.)

The adult beetle is reddish brown and about one-twelfth of an inch long. Its habits are similar to those of the confused flour beetle but it can always be distinguished by its small size. It is usually found in flour and meal, in places which have long been used for storing such products. Because of its small size it is able to penetrate the smallest cracks and may often escape ordinary cleaning.

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LARDER BEETLE (*Dermestes lardarius* Linn.)

The larder beetle is one of the larger and more conspicuous pests. The adult varies from one-fourth to one-third of an inch in length. Its general color is dark brown with a conspicuous band of pale yellowish brown across the base of the wings. The larva is covered with hairs and usually feeds about on the surface of the material which it infests, which is often ham or bacon. The life cycle requires forty or fifty days in warm weather. The adult beetles live outdoors at times, and enter the house in May and June.

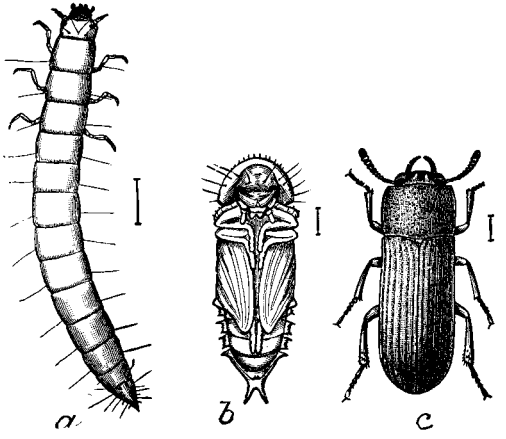

Fig. 13. Slender Horned Flour Beetle *Gnathocernus maxillosus*
a, larva; b, pupa; c, adult (From U. S. Dept. of Agr.)

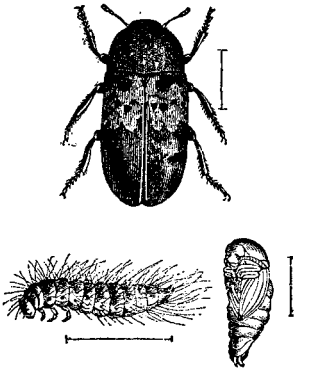

Fig. 14. Larder Beetle, *Dermestes lardarius*
Adult, larva, and pupa

A thoro cleaning of the shelves and the destruction of infested meat are the best remedies. All cracks should be sprayed with gasoline and then filled with paint.

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RED-LEGGED HAM BEETLE (*Necrobia rufipes*, De G.)

This is primarily an insect that lives on dead animal matter outdoors, but it often gains access to storerooms and infests them.

The adult is about one-fifth of an inch long, steel-blue, with reddish legs. The larvae are white grubs with two small hooks or tubercles at the tip of the body. The grubs usually work in the fatty portions of the ham and just under the skin.

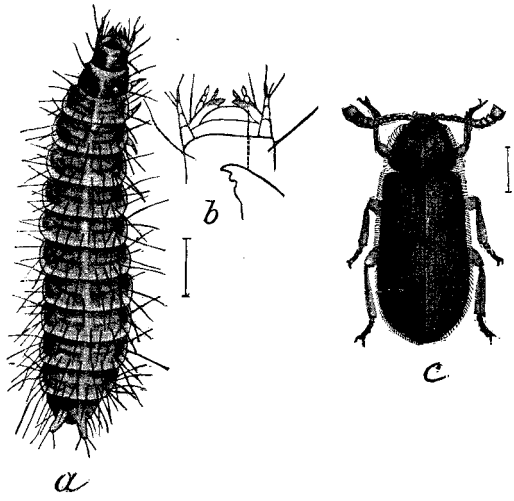

Fig. 15. Red-legged Ham Beetle, *Necrobia rufipes*
a, larva; b, head of same; c, adult (From Chittenden)

This beetle is not a serious pest in the home and can easily be detected. All infested portions of the meat should be cut out and burned. The rest will then be uninjured.

In warehouses and packing plants this beetle may prove very destructive. The best preventive treatment is to wrap the meat carefully in material that will make it impossible for the beetles to gain access. No ham or dried meat should be left exposed at summer temperature.

LARGE CABINET BEETLE (*Trogoderma ornata* Say (*tarsalis* Melsh.)

This is another insect which is a general feeder and not primarily a pest of cereals. The adult is about one-eighth of an inch long, and is black spotted with gray and light brown. The larva is brown above and white below and the body is covered with hairs that are slightly longer at the posterior end and form a sort of tail.

These beetles may attack grains and seeds as well as other organic matter.

Another species of the same genus, *Trogoderma versicolor* Cruetz, has been found in large numbers infesting dried buttermilk that was stored about fifteen months in a warehouse.

REFERENCE

Mutchler, A. J. and Weiss, H. B. The dermestid beetles of New Jersey. N. J. Bur. Statistics and Inspection Circ. 108. 31 pp. 1927.

Varied Carpet Beetle (or Small Cabinet Beetle) (*Anthrenus verbasci* Linn.) and Museum Beetle (*Anthrenus museorum* Linn.)

These two beetles resemble the large cabinet beetle in habits and importance. The adults are very small, elliptical, black beetles with gray spots, and are less than one-eighth of an inch long. The larvae are small, active, hairy grubs.

Black Carpet Beetle (*Attagenus piceus* Oliv.)

This beetle is more a pest of sacks, bolting cloth, and lint than of cereals or flour. The adult is about one eighth of an inch long, elliptical in outline, and black in color. The under surface is lighter in color than the upper and the legs and antennae are yellowish. The larvae are brown and may be distinguished from all others by a tuft of hairs, which forms a sort of tail at the end of the body.

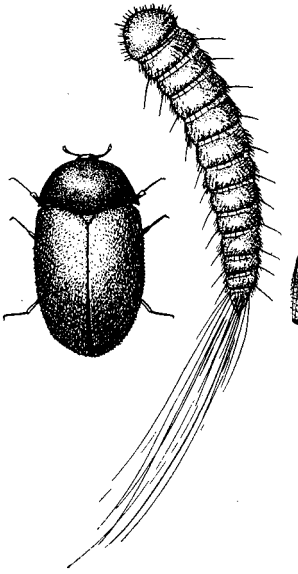

Fig. 16. Black Carpet Beetle, *Attagenus piceus*, larva and adult

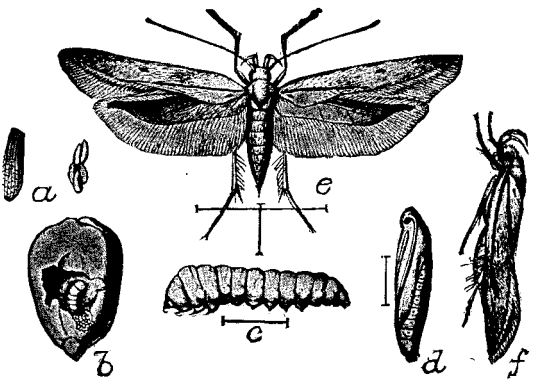

Fig. 17. Angoumois Grain Moth, *Sitotroga cerealella* a, egg; b, larva at work; c, larva; d, pupa; e and f, adult (From Chittenden)

The larvae and adults are often seen crawling over sacks, in which they eat holes. They also cause serious damage to bolting-cloth. If holes are found in any cloth about a mill the presence of the beetle should be suspected. Since its life cycle requires two years for completion, any place that is carefully cleaned at least once a year should be free from this pest.

ANGOUMOIS GRAIN MOTH (*Sitotroga cerealella* Oliv.)

This is a pest of unmilled grain and is especially troublesome in seed wheat and corn, and is one of the worst pests in the South.

The adult is small, having a wing expanse of about half an inch. It may be distinguished by the narrow, pointed wings fringed with hairs. The larvae are the only true caterpillars commonly found within kernels of grain.

In the South the adult moths lay their eggs on the green grain in the field. The larvae hatch and enter the kernels, which are entirely hollowed out by the time the larvae have reached maturity. The second generation of moths comes out to lay eggs about harvest-time. Wheat in the stack is often damaged. After the wheat is in the granary, the moths will continue to work and pass through generation after generation—six a year being recorded where the temperature is high.

In Minnesota the work of this insect has been noticeable in seed-houses and granaries. When corn or wheat has small round holes in the kernels, one each in wheat, but several in some kernels of corn, one may feel sure that the Angoumois grain moth is present. All infested material should either be destroyed or treated as described on page 72.

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INDIAN MEAL MOTH (*Plodia interpunctella* Huebn.)

This moth infests almost any food material and is one of the most common pests in grocery stores. The adult is a little larger than the clothes moth, having a wing expanse of one-half or three-fourths of an inch. One of the best distinguishing characters of the adult moth is the light grayish marking on the inner third of the fore wings. When the moth is at rest this appears as a light band across the anterior third of the wings. The rest of the wings is reddish brown.

The larva is about one-half inch long when fully grown and varies in color. The ground color is whitish but may be variously tinted with yellow, green, or even pink.

The small white eggs are laid singly or in groups on or near the material which is to serve as food for the larvae. A single female may lay as many as 350 eggs. At ordinary summer temperature the eggs hatch in four or five days and the larvae develop in about four weeks. Hence, under favorable conditions, the complete life cycle may be passed in a little more than a month.

A list of the materials infested by this moth would include nearly all products used for human food—all sorts of cereals, flour, grain (eating and embryo), dried fruits, roots, some spices, and nuts, and it has been found to be a serious pest of nut candy. When found, a thoro cleaning is necessary, as it will spread from one material to another.

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Meal Snout Moth (*Pyralis farinalis* Linn.)

This moth is more often found in dirty damp places than where it is clean and dry, and seems to prefer coarse bran and other materials to the more finely ground cereals.

The adult has a wing expanse of about three-fourths of an inch and is the most beautiful of all insects that infest stored food products. The fore wings are a dark chocolate brown at the ends while the middle is dusky white with two wavy white lines separating the lighter and darker areas on each fore wing. The coloring, together with the fact that they usually bend the tip of the abdomen up over the back when disturbed, will serve to identify this moth.

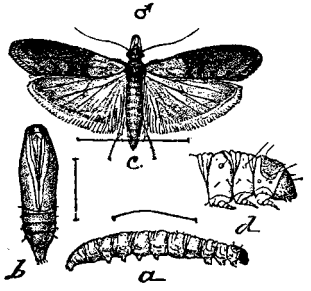

Fig. 18. Indian Meal Moth, *Plodia interpunctella*
a, larva; b, pupa; c, adult; d, head and thorax of larva (From Riley and Howard)

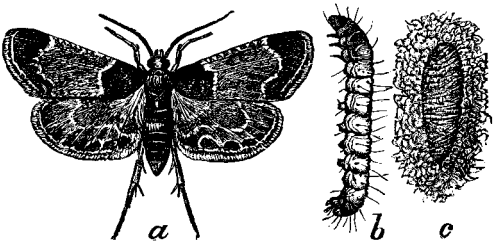

Fig. 19. Meal Snout Moth, *Pyralis farinalis*
a, adult; b, larva; c, pupa in cocoon (From Chittenden)

The larvae resemble those of the Mediterranean flour moth in their habit of living in silken tubes which they spin in the material that they

infest. They are about an inch long when mature and are a grayish white in general color, darker at the ends, and the head is brownish red. The pupal stage is spent in a silken cocoon.

The life cycle requires about eight weeks at summer temperature and the insect is usually found in damp, moldy material. It is reported as infesting hay, straw, and other roughage as well as bran, meal, and flour. As it is usually found in accumulations of material in damp places, the best remedy is a careful cleaning.

MEDITERRANEAN FLOUR MOTH (*Ephestia kühniella* Zell.)

Perhaps no insect has received more attention from flour millers than the Mediterranean flour moth. It is widespread in distribution and is said to be present in 99 per cent of the flour mills.

The adult moth has a wing expanse of less than an inch. The ground color is gray with transverse black bars. While at rest, the position in which it is usually seen, the fore part of the body is elevated, giving a distinct slope to the wings, which are wrapped about the body. The attitude of the moth while at rest is the most reliable characteristic by which to distinguish it, as the markings disappear when the wings become worn.

The larvae, when full grown, are from one-half to five-eighths of an inch long, white, often with a distinctly pink tinge. Its color and the fact that it is usually found in silken tubes that are spun in the flour, are the best distinguishing characters.

The small white eggs are laid in crevices or scattered about over machinery and in conveyors and spouts. At a temperature of between 80 and 90 degrees F., they hatch in about three days, and the larvae attain their full growth in about forty days. During the early part of their lives they are confined to their silken tubes, which they spin throughout the flour in bins, machinery, or out-of-the-way places about the mill. When they are full grown they leave the flour and search for places where they can spin their cocoons. As they crawl about an enormous amount of silk is spun, which mats together the flour and meal and clogs the bolters, purifiers, spouts, and other machinery. It is often necessary to close the mill and give all the machinery a thoro cleaning in order to rid it of the web.

Methods of fumigation and superheating are described on pages 70 and 74.

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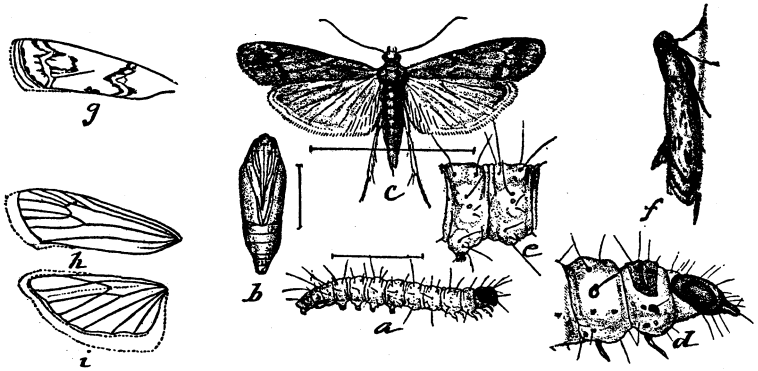

Fig. 20. Mediterranean Flour Moth, *Ephestia kühniella*
a, larva; b, pupa; c, adult; d, head and thorax of larva; e, abdomen of larva; f, adult from side; g, h, i, wings

Fig. 21. Silk Spun by Larva of Mediterranean Flour Moth
Larvae and adults shown (Lugger)

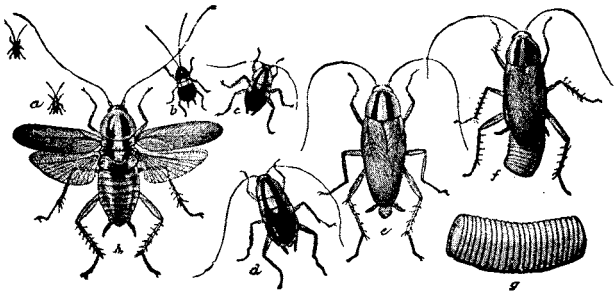

Fig. 22. German Cockroach, *Blatella germanica*
a-d, immature specimens; e, adult male; f, female with egg case; g, egg case enlarged

COCKROACHES

Cockroaches are hardly pests of stored food products but they are pests in places where such products are manufactured or stored. They may be distinguished from all other insects described in this bulletin by the fact that they are larger, run more swiftly, and are usually found in cracks or crevices where it is damp. Cockroaches are found only in buildings with a fairly high and constant temperature and where there is plenty of moisture.

The German cockroach (*Blatella germanica* L.) is the smallest and most common one in Minnesota. When fully grown it measures a little less than an inch in length and the general color is brown. It gives off a characteristic and disagreeable odor. At summer temperature the life cycle requires from three and a half to five months.

The Oriental cockroach (*Blatta orientalis* L.) adult measures about an inch and a half in length and is nearly black. It is found where temperatures are high throughout the year.

The best preventive is to have all buildings built without cracks in the walls and about the plumbing and heating. Commercial sodium fluoride or sodium fluosilicate powder should be dusted about in all cracks and crevices. The entire building should be treated at one time in order to eliminate cockroaches.

REFERENCES

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SILVERFISH (*Lepisma saccharina* Linn.) and FIRE BRATS (*Lepisma domestica* Pack.)

These small wingless insects are sometimes pests in mills, warehouses, stores, and bakeries. They are characterized by being very active, flat, and about one-half inch long. They have long antennae and three bristles at the posterior end of the body. They feed on

organic matter and are usually found in places having a fairly constant high temperature. As they attack stiffened silk, it is necessary to watch bolting cloth carefully when these pests are present.

These insects are repelled to a certain degree by fresh pyrethrum sprinkled about. They may be poisoned by mixing arsenic with paste or glue and daubing the mixture on pieces of cardboard. In using these poisons one must, of course, observe precautions to keep them away from all food materials.

For fumigation see page 74.

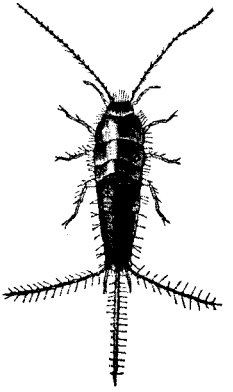

Fig. 23. Silver Fish, *Lepisma*

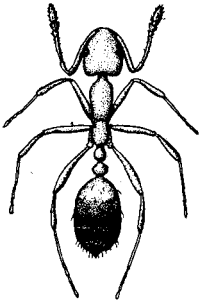

Fig. 24. Small House Ant, *Monomorium pharaonis*

Ants

Ants are often pests in warehouses, bakeries, stores, and homes. They are very persistent and when present are usually in large numbers.

Ants can be distinguished from all other insects by their long legs and slender bodies and the absence of wings in all except the queens, which are seldom seen outside the nest. In Minnesota the two most common species in stores, bakeries, and homes are the small red ant (*Monomorium pharaonis* L.) and the small black ant (*Monomorium minimum* Buck.). These can be distinguished by their color.

Ants live in colonies with one or more queens, which lay the eggs. The nest may be in a wall, a crack in the foundation, or some other secluded place. The workers go out foraging and may be found anywhere in the building traveling single file over the walls. Because of the small size, little red ants are very difficult to exclude from any container. They are very fond of sweet foods, jellies, and bakery stuff containing eggs.

In combating ants any method that is concerned merely with killing the workers on their foraging expeditions is of little value. The queens in the nests are continually laying more eggs and can usually produce

new workers about as fast as they can be killed off. In one case nearly 350,000 ants were killed in one building in six weeks. However, it is desirable to keep them out of particularly important places pending the destruction of the colony.

Ants may be kept off of furniture by placing the legs in cups of water and covering the surface of the water with a film of kerosene. Fluorine compounds, such as are advised for the control of roaches, may be sprinkled in their runways and near the nests. Sometimes this treatment is sufficient to clean up the ants within a few days. Ant sirups containing thallium should not be used by the ordinary person, thallium in extremely small doses being fatal to human beings. Arsenic sirups may be effective when other remedies fail, but precautions must be taken to keep children from being accidentally poisoned.

The only way to rid a place of ants is to locate the nest and kill the queen. The nest can usually be located by putting some granulated sugar in a place that is frequented by the ants. Soon a long file of ants will begin carrying the sugar to the nest and they can be followed. When the nest has been located, carbon disulphide may be poured or squirted into it, and the opening securely closed. Carbon disulphide is very explosive and should never be used near a fire or a light of any kind. Kerosene may be used but it is less effective.

Cheese Skippers (*Piophila casei* L.)

The maggots called cheese skippers infest hams, bacon, and cured fish, as well as cheese. The adult is a black fly about half the size of the common housefly. The maggots are white and legless. They propel themselves by bending in an arc and then straightening out suddenly. They may also crawl about, especially when they have attained full growth and are seeking a crack in which to pupate.

The adults fly about and lay their eggs on meat or cheese. The life cycle requires three or more weeks, depending upon the temperature.

Cheese and cured meats should be stored at a temperature of less than 43 degrees F. or carefully protected with a screen having at least 24 meshes to the inch. Infested portions may be cut out and thrown away and the remainder carefully examined daily to make sure that all larvae have been disposed of.

REFERENCES

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Simmons, P. The cheese skipper as a pest in cured meats. U. S. Dept. of Agr. Bull. 1453. 1927.

Book Lice (*Atropos divinatoria* Mull.)

These small lice-like insects seldom become of any great importance in stored food products. There are several species which may be present but the one mentioned is the most common.

Because of the small size they may be confused with mites, but they are very different. Book lice are active six-legged creatures with large heads and rather long antennae. They live in straw, cereal products, wheat, seed, and other organic material.

All badly infested material should be heated to a temperature of 140 degrees F. or fumigated or burned. Infested storerooms should be thoroly cleaned, for these pests can live in cracks and crevices. All cracks should be sprayed with kerosene or one of the sprays described on page 82. If convenient, the whole place should be heated or fumigated. See pages 70 and 74.

MITES (*Tyroglyphus* sp.)

Mites are the smallest of the ordinary pests of stored food products and may also be the most abundant.

Several species are found in stored food products. They are not more than a thirty-second of an inch long and their whitish color makes them very difficult to be seen in flour. When examined with a microscope they are found to be sparsely covered with rather long hairs.

When present in large numbers they give off a sweetish, musty odor, which is so characteristic that one who has had experience can detect their presence without having seen them. If some of the flour which is suspected of containing mites is piled in the light, the mites will crawl away from the light and the pile of flour will gradually flatten out.

It may be safely said that there is no more difficult pest to combat. Their small size, their rapidity of multiplication and development, and their peculiar habits fit them for life in stored food products. Under certain conditions, some of the mites pass into a resting stage known as "hypopus." In this condition they are covered with a hard crust that prevents them from drying out and they can live without food for months, during which time they may be blown about with dust or carried about on mice or flies. If at any time they come into favorable conditions they will emerge from this peculiar stage and reproduce. All the mites may seem to have disappeared from a bin which was formerly infested, but as soon as new material is stored in it they again appear.

There are often several species of predaceous mites associated with *Tyroglyphus* and in some cases it has been supposed that they preyed upon *Tyroglyphus* and eliminated them. The observations of the author have shown that while the predaceous mites do actually destroy many of *Tyroglyphus,* they have least effect when there is enough moisture for the rapid development of the host, and the greatest effect in dryer

places. However, in these latter places many of the *Tyroglyphus* are in the hypopial stage, in which they apparently escape their enemies.

The records show that mites have been a pest for ages but our present methods of transportation and of storage of large quantities of material in central warehouses make it possible for serious infestations to occur. It has seemed that mite infestations are on the increase, but it is hoped that this is apparent rather than real. Any outbreak should be thoroly investigated and wiped out as soon as possible.

A list of the foods of these mites includes about every one known. All sorts of cereal products, cotton-seed and flax-seed meals, grains, cheese, meats, dried fruits, bulbs, roots of plants, skins, hair, feathers, and many other organic materials are known to have been attacked.

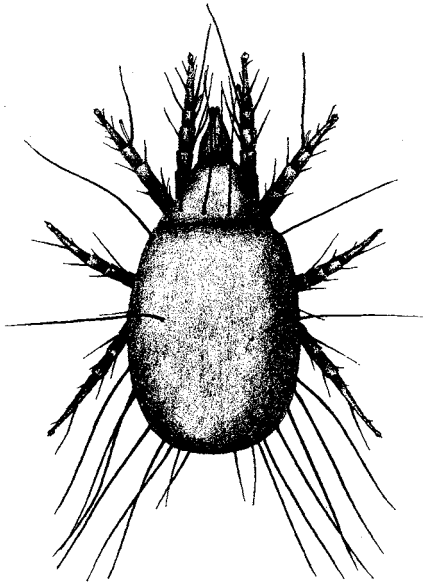

Fig. 25. Mite, *Tyroglyphus* sp.

It has recently been discovered that mites require a minimum of about 11 per cent of moisture in their food. Hence many of the foods listed above may remain free from mites as long as the moisture content is below this point. However, when a small portion of the food has the required 11 per cent of moisture, the mites start work in this portion, provided it becomes infested. When once started they raise the moisture content of the surrounding material by giving off moisture themselves. In this way they may cause trouble in places which originally seemed too dry for them.

Strenuous measures must be resorted to. Fumigation is not very effective. A careful inspection should be made and all infested material should be burned or heated to a temperature of at least 140 degrees F. Directions for fumigation are given on page 72.

After the cleaning has been done, all corners, cracks, and crevices should be thoroly sprayed. If there is no danger of fire, gasoline or kerosene may be used. A safer spray is carbolic acid emulsion. This has a strong odor which may be objectionable, but it is effective whenever it comes in contact with the mites. The formula for the spray is given on page 82.

STERILIZATION

Oven Heating for Small Quantities

Cereal products that are to be stored during hot weather or that for any reason are suspected of containing insect eggs, should be heated. Also when insects have been discovered in one of several lots of material, all should be "sterilized."

The material should be placed in pans, not more than an inch and a half or two inches deep. The pans may then be placed in the oven and the heat turned on. A gas oven, with the fire as low as it will burn well, will heat the surface of the material to a temperature of about 180 degrees F. in fifteen minutes. The center of the material will then have reached a temperature of about 120 degrees F. Figure 26 shows the range of temperature. In this case the heat was turned off after the fifteen minutes and the material was left in the oven with the door closed for half an hour.

When any cereal product is used, other than one used for making raised bread, the only danger from high temperature is that of scorching. For "rising flour" a temperature of 174 degrees F. must be avoided and a thermometer should be used. For ordinary breakfast foods and meals a thermometer is advisable but not absolutely necessary. Frequent stirring will give more uniform heating and will reduce the possibility of scorching the material.

Hot-Room Method for Grains, Beans, Peas, and Other Seeds

Grain handled on a large scale may be passed through a grain dryer at the elevator and thus be heated to at least 130 degrees F. This will serve the double purpose of drying the grain and killing the insects. Dryers on the market are well adapted to this purpose.

Seeds in sacks and any cereals or other products known to be infested may be heated in a room designed for the purpose. A seed-house or mill may well provide a small, well-insulated room with a large radiator for heating the room to about 130 degrees F. and keeping

it at that temperature. Sacked material should be left in the room until that in the center of the sacks has reached the temperature of the room.

Small lots of beans and other seeds may be heated in the oven. The precautions given with regard to temperature must be observed.

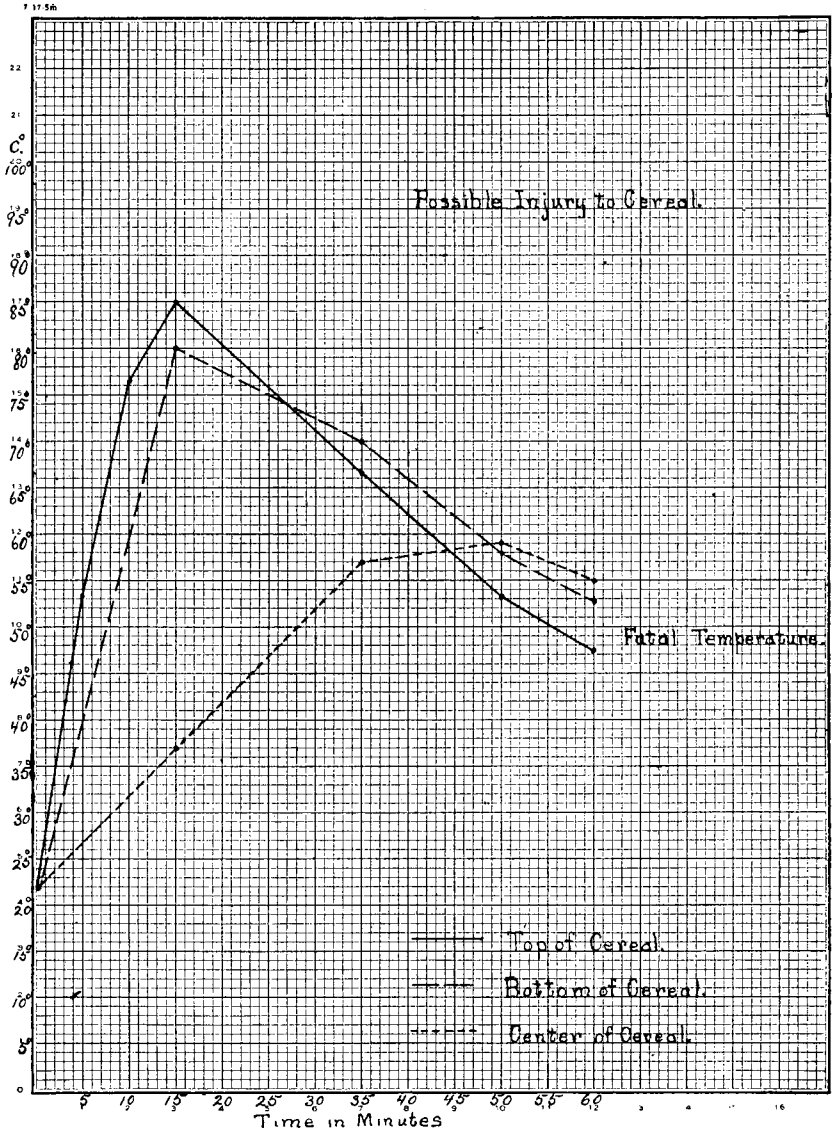

Fig. 26. Temperature of Cereals During Process of Heating in Oven of Gas Range

Experiments on the effect of temperature on the percentage of germination of seed have shown that a temperature of 125 to 130 degrees F. for eight hours or more will have little effect. Most of the

trouble reported seems to be due to a failure to observe proper precautions. It is necessary to protect seeds near the source of heat much more than those some distance away.

Experiments have also shown that heating to a temperature from 124 to 154 degrees F. for two hours has practically no effect on the germination of beans and that this is about six times as long as is necessary to kill the weevils. The author states that the effect upon all seeds was much the same.[1]

"Continuous Process Sterilization" for "Sterilizing" Products in Factories

The safest method of handling special products is to "sterilize" them and pack them in tightly sealed containers. Such products will remain free from insects for all time provided the packages are not broken open or exposed to insects which will eat their way into the packages.

"Sterilization," as used in this connection, means freeing the product of all insect life. In its true sense sterilization means doing away with all life, including bacteria. Since bacteria are present everywhere, are very much harder to kill than insects, and relatively few of them are harmful, there is no reason why ordinary cereals should be made sterile in the true sense.

The "sterilization" of cereal products is usually accomplished by means of fumigation, electricity, or heat. The heat method is almost universally employed. Fumigation is slow, expensive, and accompanied by a certain amount of danger. Aside from a few secret processes this method is seldom used.

Electrical methods include the use of (a) X-ray and (b) static electricity. The X-ray method was developed and used in "sterilizing" cigars against the cigarette beetle. This method is relatively expensive, requiring the installation of special equipment. It should be supervised by some one who thoroly understands the action of X-ray and the application of it to the problem of cereal "sterilization." This method is limited by being unable to act through a material of any great thickness.

The use of static electricity for killing insects and insect eggs is still in the experimental stage. This method has the advantage of treating the product after it has been sealed in the packages. As the electricity passes through paper with little interference, it is possible to do away with all danger of having insects enter the material between

[1] de Ong, E. A. Effect of excessive sterilization measures on the germination of seeds. Jour. Econ. Ent. 12:343-345. 1919.

the time of "sterilization" and the sealing of the packages by exposing the sealed packages to the electricity.

There is no doubt about the possibility of killing insects by means of static electricity, but the possibility of using electricity satisfactorily under factory conditions must be more fully investigated.

Heat is the oldest, most common, and most satisfactory method of "sterilizing" products. The theory is very simple. The product must be heated until the coldest part of it is at a temperature which is fatal to insects in all stages. At the same time care must be taken that the temperature of the hottest portion does not reach a point that will be injurious to it. Experiments on many different insects have shown that all species are not killed by the same degree of temperature and that the temperature required to kill a given species differs under different conditions. However, few insects can endure a temperature of more than 125 degrees F. for even a short time.

The temperature that will injure cereal products depends on the nature of the product and on its moisture content. It has been said that the "strength" of wheat flour is ordinarily injured by a temperature of about 174 degrees F. Products that are not used for raised bread or pastry can endure a much higher heat, in fact many of them can withstand anything less than actual scorching.

Heat should be applied just before the material is placed in the package and it may be derived from steam, hot air, or electricity. Any type of machine that will keep the material in constant motion and heat all portions equally, is satisfactory. Machines on the market should be examined with the view of determining which will produce the most even and constant temperature combined with economic installation and operation.

The cereal should pass from the sterilizer directly to the packer. There is nothing about sterilization that will prevent insects from reentering the product, it simply kills all eggs and all stages of insects present at the time of treatment. If the product is then packed and sealed it will be permanently free from insects. Figure 27 illustrates a satisfactory method of handling a product for sterilization and cooling. It will be noticed that this product remained at a temperature above that which is fatal to insects for half an hour after the packages were sealed. Any insects that were in the packages before they were filled would have been killed by the temperature of the product after it was in the package.

Some complications may arise with regard to the moisture in the product. A certain amount of moisture will be given off from the product in the form of vapor. Ordinarily this may accumulate like

dew upon the product as soon as it cools again. This does not mean that the moisture content of the product has been increased. On the contrary, it is decreased because some of the vapor will escape. When first cooled, most of the moisture will be condensed near the outside of the package because this will be the coolest place. Later, however, the material near the center of the package will absorb the excess moisture from that near the outside and the moisture will again be equally distributed throughout the product. If water has been added in the process of manufacture, it is necessary to pass the product into a bin after it is cooled, where it remains while the moisture is being redistributed. Such bins must be closely guarded in order to prevent insects from getting into the product.

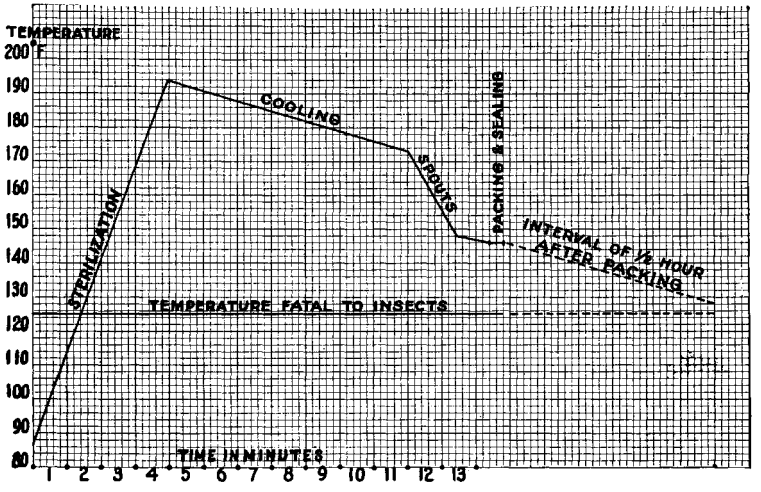

Fig. 27. Temperature of Cereals During Process of Sterilization and Packing

Heat Method of Treating Mills and Warehouses

The heat method has been used principally in the southwestern part of the United States. It was employed long ago in France but was developed in this country by Professor George A. Dean, of Kansas. However, the method has since been used throughout the United States and in Canada. Where it has been possible to use heat it has been considered superior to fumigation in that it penetrates better, thus being more effective against the beetles that hide in cracks. It also kills the eggs to a greater extent than does fumigation. It is also safer and cheaper than fumigation. In Ohio it is said that the cost of the heat treatment is about one-fiftieth of that of the hydrocyanic acid gas treatment.

A temperature of 120 degrees F. is fatal to insects in a few hours. However, it is necessary to have this temperature actually penetrate to

the insect itself and for this reason it is well to have the temperature higher and to hold it for a longer time.

Not all buildings are tight enough to be heated to this temperature, but as a general rule any mill that can be heated to a temperature of 70 degrees F. in the winter can easily be heated to 120 during the hot days of summer. Where there is not enough radiation it is often cheaper to install the necessary pipes than to fumigate with hydrocyanic acid gas. When pipes are installed they should be near the floor and well distributed about the sides of the building. As heat rises, it will be necessary to have more radiation on the lower floors than on the upper ones. The following scale of cubic feet of capacity to each square foot of radiation has been suggested.[2]

Floor	Cubic feet	Floor	Cubic feet
1	50	4	90
2	60	5	110
3	75		

"Tables showing radiating surface per linear foot, and the linear feet required to make one square foot of radiating surface:

Size of pipe, inches	Square feet of radiating surface per linear foot	Linear feet of pipe per square foot of radiating surface
1	0.346	2.9
1¼	.434	2.3
1½	.494	2.0
2	.622	1.6
2½	0.753	1.3

"In case steam pipe is used for the radiation, either 1¼ or 1½ inch pipe is recommended as the most practical size."

Water taps should be provided to draw off the water that collects as a result of the condensing of the steam when the pipes are cold. A pressure of from 25 to 50 pounds should be used in order to heat the building rapidly.

A hot day in summer should be chosen for heating. A windy, cold, or rainy day is obviously unsuited. If Saturday is chosen and the heat is turned on just as soon as the machinery is stopped, the desired temperature should be reached some time on Sunday, and should be held for several hours in order that it may penetrate any accumulations of flour. Early Monday morning the heat may be turned off and the windows opened to allow the place to cool off in time for the regular business of the day.

Thermometers should be put in three or four places on each floor of the building and the heating should be continued until the thermometer near the floor of the first story shows a temperature of at least 120 degrees F. and for some time.

[2] Dean, G. A. Mill and stored grain insects. Kan. Agr. Expt. Sta. Bull. 189. 1913.

Precautions should be taken to see that the building is tightly closed and that no part of any room is cut off from free air circulation with the rest of the room. Each floor of the building should be shut off from all others. All elevators and carriers should be shut. Furthermore, the heating should be persisted in until the minimum temperature of 120 degrees is reached. Failures with this method are due to careless temperature regulation.

REFERENCE

Goodwin, W. H. Heat for control of cereal insects. Ohio Agr. Expt. Sta. Bull. 354. 1922.

Special High Temperature Quarantine Room

A special room should be provided in every mill, warehouse, or wholesale house for heating infested goods in order to kill the insects. It should be tightly built and insulated with building paper. It should have at least one square foot of steam pipe radiation for each 50 feet of cubic contents. A room 10 feet square and 10 feet high will contain 1,000 cubic feet of space and should have 40 linear feet of 1½ inch steam pipe placed around the edge near the floor. If fifty pounds of steam pressure is available, the room can be quickly heated to 120 degrees F.

A cereal product that is infested or is even suspected of being infested should be put into this quarantine room at once and heated. In this way a general infestation may be avoided. The saving will more than pay for the cost of the room.

Low Temperature Method or "Freezing Out"

In Minnesota it is possible materially to reduce the number of insects by "freezing out." A period with the temperature well below zero should be chosen, if possible. All water pipes must be drained and the whole place opened. All doors and windows should be opened in order that the temperature may fall as rapidly as possible.

Several days should be allowed, and then the temperature should be run up rapidly. Many millers make this a regular practice and consider it a valuable precaution. However, it does not kill all the insects.

FUMIGATION

Fumigating Grain or Seeds, Flour, and Other Cereal Products in Sacks or Bins

Small amounts of material may be put in cans, barrels, bins, or boxes, or piled together in sacks and fumigated. In all cases it is necessary to be able to confine the gas so that it will penetrate the material before it escapes. Larger amounts may be in bins, granaries,

elevators, or freight cars. Sacks of cereal or grain may be piled together in the corner of a room and covered with blankets on the exposed sides, but this method is less satisfactory than the others. For larger amounts, a small tight building made especially for the purpose is most satisfactory, and as it may be needed every year it is also economical.

Ethylene dichloride is an effective fumigant for stored products in sacks or bins. Its advantages are low cost, low fire hazard, rather high toxicity to insects, and relatively low toxicity to persons. It burns, altho not readily. When mixed three parts to one of carbon tetrachloride, it is free from fire hazard. This mixture is obtainable already prepared. The odor of ethylene dichloride is not at all objectionable. Altho the danger of asphyxiation while using the fumigant is not very great, it has an anesthetic action. If much of it is inhaled a feeling of giddiness may ensue. If this happens, the user should go into the open air at once. Ethylene dichloride evaporates rather slowly, so it should be exposed in thin layers in shallow pans or thrown directly on grain or exposed by soaking bags in it. Evaporation may be accelerated by blowing a current of air from a fan over the fumigant in pans. The vapor is much heavier than air. Ethylene dichloride has a specific gravity of 1.27 at 67 degrees; a gallon weighs 10.4 pounds. Fourteen pounds of the 3 to 1 mixture to 1,000 cubic feet is an effective dosage at ordinary temperatures. It should be allowed to act for twenty-four hours. It is usually not wise to attempt to fumigate when the temperature is below 60 or 65 degrees F.

REFERENCES

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Hoyt, L. F. Some fumigation tests with ethylene dichloride–carbon tetrachloride mixture. Ind. and Eng. Chem. 20:460. 1928.

——— Further fumigation tests with ethylene dichloride–carbon tetrachloride mixture. Ind. and Eng. Chem. 20:931. 1928.

Roark, R. C. and Cotton R. T. Tests of various aliphatic compounds as fumigants. U. S. Dept. of Agr. Tech. Bull. 162. 1929.

Russ, J. M. Ethylene oxide and ethylene dichloride; two new fumigants. Ind. and Eng. Chem. 22:844. 1930.

Carbon tetrachloride is likewise a liquid at ordinary temperatures. It evaporates at about the same rate as ethylene dichloride. It is somewhat heavier, its specific gravity being 1.58. The odor is not objectionable altho it is not as pleasant as that of ethylene dichloride. The same directions and precautions should be observed as to the method of application. Carbon tetrachloride is non-inflammable, in fact it is sometimes used as a fire extinguisher. The main disadvantage in its use is its low toxicity to insects. It is only about a fifth as effective as the ethylene dichloride mixture. The dosage should be from 20 to 30 pounds to each 1,000 cubic feet of space. The amount

depends upon the temperature; in hot weather less fumigant is required than in cold. This is true of most fumigants, but temperature seems to affect the toxicity of carbon tetrachloride much more than it does most of the other common fumigants.

Carbon disulphide is used in the same way as carbon tetrachloride. It is better known and more satisfactory. However, it is explosive and should never be used near a light or a fire. For this reason it should be limited to use in buildings built for the purpose. A carbon disulphide fumigation should never be undertaken in a granary, elevator, or mill without obtaining the permission of the insurance underwriters. Ordinarily the use of carbon disulphide voids the fire insurance policy. Altho it is somewhat more effective in killing insects, its use is not advised in view of the safer materials that have been made available within recent years.

Chloropicrin is one of the tear gases used in the World War. Its advantages are its extremely high toxicity to insects, its non-inflammability, and its warning qualities. Altho it is toxic to human beings, very small non-injurious traces of it are so annoying that one absolutely can not remain near exposed chloropicrin. On the other hand, it does not evaporate readily. It must either be sprayed into the space to be fumigated or be diluted with equal parts of carbon tetrachloride so as to improve its evaporative powers. It is often necessary for the operator to wear a gas mask in making a chloropicrin fumigation. A further disadvantage is the degree to which it clings to fumigated goods and resists airing. Two pounds of chloropicrin to 1,000 cubic feet of space is the dosage required to fumigate bins and tanks.

REFERENCES

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Strand, A. L. Chloropicrin; new fumigant for mill and household insects. Minn. Special Bull. 102. 1926.

Formaldehyde is not effective as a fumigant against insects and it is injurious to flour. For these reasons all are warned against its use in this way.

Sulphur dioxide is a very effective fumigant against insects. Even a small concentration will kill insects in a short time. However, it has a very detrimental effect upon the flour, particularly if it is moist, and is not recommended.

Fumigation of Mills, Factories, Warehouses, Stores, and Homes

Many mills and factories are fumigated or heated annually as a matter of general practice. Other places are fumigated to eliminate a bad infestation that has become general throughout the place. It is

good practice to fumigate or heat annually and thus prevent any general outbreak of insects. The choice between heat and fumigation should be made after studying the requirements of each method and the situation to be dealt with.

Hydrocyanic acid gas is perhaps the most satisfactory fumigant to be used on a large scale. It is very poisonous and must always be used with the greatest care. However, when all precautions are taken the work can be safely done.

First of all, the building to be fumigated must be sufficiently isolated from others that none of the gas can do injury in neighboring buildings. If other buildings are close to the building to be fumigated, all windows and doors on the adjoining side should be closed tight, or, better still, the buildings should be vacated during the period of fumigation.

Next, the building to be fumigated should be made as nearly air tight as possible. This will mean the stopping of all cracks about the windows and doors. Strips of newspaper that have been wet with water may be put over cracks and will stick tightly during the fumigation. Also each floor should be shut off from the others. At least one window on each floor should be arranged to open from the outside so that when the fumigation is over the building may be aired before anyone enters.

There are a number of methods of obtaining the gas for fumigation. The oldest and most common one in practical use is the "pot method," using sodium cyanide and sulfuric acid. Directions for this procedure are given, as it may be necessary sometimes to use sodium cyanide in fumigating houses when calcium cyanide is not obtainable.

The first step is to measure carefully the cubic contents of each room, making no allowance for machinery. Then the amounts of material should be computed from the cubic measurements. One pound of sodium cyanide should be used for each 1,200 cubic feet of space in the basement, every 1,400 cubic feet on the first floor, every 1,500 cubic feet on the second floor, every 1,800 cubic feet on the third floor, and about a pound to every 1,900 cubic feet on each floor above. More cyanide is used on the lower floors because the gas is light and will rise to the upper floors.

The proportion of the chemicals should be as follows:

Sodium cyanide (98 per cent pure), 2.5 pounds
Sulphuric acid (specific gravity 1.83), 5 pints
Water, 7.5 pints

This formula requires more acid than some formulas but it ensures the using of all the cyanide and thus makes it all available for fumigation and reduces the danger of having any left in the jars.

It will be necessary to have a four-gallon stone jar for each two and a half pounds of cyanide and the proper proportions of acid and water. A convenient method of making up a list of materials needed for the fumigation is to make a table showing the number of cubic feet on each floor, the amount of sodium cyanide, sulphuric acid, and water required for each floor, and the number of jars required in each case. The number of pounds of sodium cyanide needed may be computed as shown above. It will require twice as many pounds of sulphuric acid as of sodium cyanide, and, as stated above, one jar will be needed for each two and a half pounds of sodium cyanide.

The sodium cyanide should be at least 98 per cent pure and in lumps not larger than the size of an egg. If larger, they must be broken up. It should be broken up and weighed out in the open air. It should be handled with gloves and the greatest care should be taken to see that none of it gets into the eyes or mouth. Each two and a half pounds of sodium cyanide should be placed in a No. 8 paper sack and this inside a No. 10 sack. This will lessen the danger of the sodium cyanide spilling while the sacks are being carried to their places.

The water should be poured in the jars first and the acid should be added slowly to prevent the jars from cracking as a result of the heat which is generated when the water and acid mix. Never pour the water into the acid. The acid should have a specific gravity of at least 1.83. It should be measured and carried about in stone or graniteware vessels for it will injure metal. Those handling it should be careful not to get it on the hands or the clothing.

The jars with the acid and water in them should be distributed throughout the building in accordance with the table suggested above. The jars should not be placed within two feet of bags, belts, or machinery, for some of the acid may boil over on them. The sacks of sodium cyanide should then be placed beside the jars ready to be put into them when everything is ready for setting off the charge.

Setting off the charge.—There are two methods of setting off the charge. One is to start on the upper floor and walk rapidly from jar to jar and place the sacks of cyanide in the jars by hand. When the rooms are small and unobstructed by machinery this method is satisfactory. Remember that one good breath of the gas is enough to overcome a man and that the gas begins to rise from the jars about twenty-five seconds after the cyanide is placed in the acid. Therefore, if there are more than a dozen jars to a floor and if there is much machinery in the way, the stringing method should be used.

In the stringing method the sacks of cyanide should be tied securely with strong fish line or other strong cord to make sure than none of them will fall into the acid before everything is ready. They are then

suspended an inch or two above the jars by strings which pass through screw eyes in the ceiling above the jars and then all strings go to one point at the door or stairway. In this way all the strings may be loosened and all the charges set off at one time.

When everything is ready, all workmen should be called outside the building. If the charges are to be set off by hand, two cool-headed and responsible men should be chosen to do the work. If they start at the top and work rapidly from floor to floor there should be no difficulty. If the stringing method is used it is only necessary to release the strings and lower the sacks on each floor. The building should then be locked and marked so that no one will enter it.

The length of time of the fumigation should be at least eighteen hours, or better still, twenty-four or thirty-six hours. If it is started on Saturday evening, the mill can be opened Sunday evening or early Monday morning. For good results the mill temperature should be about 70 degrees F.

The building should be ventilated by means of the windows that have been arranged to open from the outside. After these have been open about two hours, the building may be entered and all doors and windows opened. No one should remain in the building for more than a few minutes until all the doors and windows have been open for from fifteen to thirty minutes.

Emptying the jars is the next order of work. While carrying the jars out make sure that all the bags of cyanide have actually been placed in the jars. If any were forgotten or if some of the strings failed to lower the bags, these should be carefully removed and not thrown out with the liquid in the jars. The jars should be emptied into a hole in the ground or in a sewer. Care should be taken not to breathe any vapor which may arise from the liquid or to get any of the acid on the skin or clothing. When the jars are thoroly washed they are fit for use for any purpose.

Cautions

Use good materials

Sodium cyanide, 98 per cent pure

Sulphuric acid, 1.83 specific gravity.

Do not let either cyanide or acid come in contact with skin or clothing.

Measure the rooms accurately.

Have the building closed tight.

Distribute the jars uniformly in the rooms.

Do not permit any one to enter the place between the time when the charge is set off and the time when the ventilators have been opened.

In mills a permanent piping system sometimes may be economically installed by means of which liquid cyanide can be introduced under

pressure from outside the building. This is the safest type of cyanide fumigation, for by its use there is no excuse for any operator being caught by the gas.

The best source of cyanide gas for general work is calcium cyanide. The material is easily and quickly applied. Its use, altho attended by danger from the gas, allows the operator to work so much more quickly than with the pot method that the danger is much reduced. Granular calcium cyanide evolves hydrocyanic acid gas upon exposure to the moisture of the atmosphere. It is merely necessary to lay down strips of paper in the rooms to be treated, and then, when all is in readiness, to sprinkle the proper amounts of cyanide on the paper, and close the building. The same precautions must be taken in conducting the work as in the case of the pot method. After the fumigant has acted for twenty-four hours, the building should be opened and aired before any one enters unless a gas mask is worn. The papers and the cyanide residue should be taken outdoors and burned or buried. **Do not dispose of them in the furnace as some gas may still be given off.**

Granular calcium cyanide may be used for fumigating grain in elevators. Cyanide is fed into the grain stream just before it enters the elevator, thus insuring even distribution of fumigant particles throughout the mass of grain.

Ethylene oxide is a very effective fumigant of recent discovery. Altho a gas at ordinary temperatures it can be handled readily as a liquid under pressure in gas cylinders. Owing to its low boiling point, ethylene oxide is effective against insects at much lower temperatures than most fumigants, even at grain temperatures below 50 degrees Fahrenheit. It is more toxic to insects at ordinary temperatures than the other fumigants, altho it is not nearly so dangerous to many as cyanide. On account of its inflammability it is usually mixed one part with nine parts of carbon dioxide, either solid (dry ice) or liquid. It is most convenient to use a ready prepared liquid carbon dioxide-ethylene oxide mixture (trade name, "Carboxide"), sold in gas cylinders of various sizes. When a room is fumigated the correct amount of Carboxide is brought in, the cylinders being placed upright in locations easily reached, just as in locating the pots in the sodium cyanide fumigation. The same precautions must be taken that the entire building is not occupied during the fumigation. It is well to remember when turning on the gas in each cylinder to keep the nozzle turned away from the operator and not to turn it on too rapidly so that the cylinders may be tipped over by back pressure. Precautions must be taken against being trapped by an overdose of the gas before the cylinders are all opened. Ethylene ovide is used at the rate of two pounds per 1,000 cubic feet, or "Carboxide" at the rate of 20 pounds.

Carbon dioxide, altho comparatively ineffective itself as a fumigant, stimulates insect respiration, and so increases the effectiveness of ethylene oxide when mixed with it. Because the two gasses are of about the same weight they do not separate, either when the liquid mixture is stored in cylinders or after the gases have been released.

A dry ice-ethylene oxide mixture is sometimes poured directly on the grain stream as it enters an elevator. It is used in the proportion of 3 pounds ethylene oxide to 30 or 35 pounds dry ice for each 1,000 bushels of grain. The dry ice is broken into small pieces an inch or two in size, and the ethylene oxide poured over it in buckets, which may be distributed to the points where the application takes place. Dry ice has a temperature of 110 degrees below zero, and will cool grain when the latter is too warm or will maintain a low temperature if the grain is transferred in warm weather.

Ethylene oxide should not be used to fumigate seeds as it affects germination more than do most fumigants.

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Russ, J. M. Fumigation with ethylene oxide. Ind. and Eng. Chem. 22:328. 1930.

———— Ethylene oxide and ethylene dichloride, two new fumigants. Ind. and Eng. Chem. 22:844. 1930.

Duval, L. Treating grain for the destruction of injurious insects. Food Industries, vol. 2 December, 1930.

Chloropicrin is a very effective fumigant against localized infestations of insects in flour and cereal mills. It can be used inside such milling machinery as elevator legs, grinding rolls, purifiers, certain kinds of dusters, bins, and tanks. In the milling machinery it can be most effectively applied by atomizing into the heads of the elevators. In bins and tanks it can be poured on sacks hung in the top openings. The dosage is 5 pounds of chloropicrin for each 1,000 cubic feet of volume of the machinery connected with the elevators. It is applied to the heads and the mill is operated during the process. In bins and tanks 2 pounds per 1,000 cubic feet is sufficient.

For references, see page 74.

PENETRATION AND RETENTION OF FUMIGANTS BY FOOD PRODUCTS

The depth of penetration of a fumigant is proportional to the concentration of gas and the time during which it acts. Large bags of flour should not be piled closely, but should be separated so that they are exposed to the gas on all sides. When a fumigant is applied to

grain in a tight bin, the downward diffusion of the gas is not so rapid as is usually supposed. The concentration of a heavier-than-air fumigant does not become stronger at the bottom of the bin than toward the top, but varies inversely with the depth below the grain surface. This is the result of adsorption of gas by the top layer of grain, preventing much of it from moving downward. The dosage of fumigant must be great enough to provide a toxic dose for the insects after the grain has taken up all it can. When large quantities of grain are fumigated it is necessary to mix the fumigant with the grain while the bin or elevator is being filled.

Various products differ in their capacity for adsorbing gases. Nut meats and other food products rich in fat adsorb more gas than others. Consequently they require correspondingly greater dosages and longer time of airing to free them of gas. Dry foods take up only traces of fumigant.

While hydrocyanic acid gas is very poisonous and is very soluble in water, it is gradually given off by foodstuffs when they are exposed to the air after fumigation. The Public Health reports describe experiments in which it was found that mice were not affected when closely confined with bread and milk which had been recently fumigated with an ordinary amount of hydrocyanic acid gas. The mice even ate this food soon after fumigation without showing symptoms of poisoning. When the dosage was doubled and the time of fumigation prolonged, some of them died. Those that died had not eaten any of the food but were evidently killed by the gas given off by the bread and milk. When the food was aired before feeding it to the mice there were no symptoms of poisoning. The conclusion of the one who performed the experiments is that the possibility of poisoning from food materials which have been exposed to cyanide gas is very remote.

At lower temperatures adsorption is increased. Hence temperature is important in the fumigation of grain or cereal products aside from its relation to the toxicity of the fumigant or the activity of the insects being fumigated. At higher temperatures less fumigant is made ineffective by adsorption on the product.

When speed is essential, vacuum vaults can be used for fumigation. When speed is not important and space is available, vaults at ordinary atmospheric pressure are satisfactory for most goods. Some materials, such as dried figs and prunes in packages, package cereals, and baled fibers, because of their dense nature and tight wrappings, are best fumigated under vacuum. When air is partially removed from goods under vacuum, the fumigant penetrates them very rapidly. Much

heavier dosages of fumigant are required, however, than at ordinary pressures.

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Schenck, G. and Dean, G. A. Hydrocyanic acid gas penetration tests in 140-pound bags of flour under atmospheric conditions. Jour. Kan. Ent. Soc. 2:60-66. 1929.

Cotton, R. T. Carbon dioxide as an aid in the fumigation of certain highly absorbtive commodities. Jour. Econ. Ent. 23:231-233. 1930.

Effect of Fumigants on Baking Quality of Flour

In practically all cases where the fumigation of flour results in injury to its baking qualities it can be shown that the flour is used before it is sufficiently aired. Dean and Swanson report that carbon disulphide affects the quality of flour more than does hydrocyanic acid gas. This is only true to any extent, however, in the case of hard wheat flours, and even then only when the flour is worked up and baked immediately after fumigation. According to Chapman and Johnson, deleterious effects are noted in bread produced from flour in which chloropicrin is present. Chloropicrin retards fermentation and affects the physical condition of wheat proteins. When flour is exposed to the air for sufficient time to eliminate the gas it shows complete recovery from chloropicrin treatment. Chloropicrin seems to be more difficult to remove by airing than most of the other fumigants.

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Dean, G. A. and Swanson, C. O. Effect of common mill fumigants on the baking qualities of wheat flour. Kan. Tech. Bull. 178. 1911.

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Effects of Fumigants on Seed Germination

It has been demonstrated that, with the exception of ethylene oxide, the fumigants advised in this bulletin have no injurious effect on the germination of seeds when they are used at the recommended dosages. Seeds, however, must be thoroly mature and dry, otherwise they may be injured by fumigation. Ethylene oxide seriously injures the viability of seeds, and should not be used for their fumigation.

REFERENCES

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SPRAYING FLOORS, WALLS, AND OTHER SURFACES

As careful cleaning can not always be followed by heating or fumigating, it is often desirable to use a spray. Once a year the cleaning should be followed by a thoro painting that will fill all cracks where pests may hide. If the paint is applied with an air brush it will fill practically every crack and will thus make the surface easily cleaned of all pests.

Several commercial sprays on the market seem to be efficient as contact insecticides, that is, they kill insects when they actually come in contact with them. Many of these sprays have a strong odor that may act to a certain extent to repel insects. Kerosene or gasoline may be used as sprays, but precautions must be taken against fire.

A very satisfactory spray has been made by using a 15 or 20 per cent emulsion of carbolic acid held in suspension in a one per cent solution of soap in water. This has proved efficient when used against mites and other pests. Its odor may be objectionable about food, but if it is used in vacant rooms or freight cars and a few hours' time is allowed for it to evaporate before food products are brought into the place, there should be no difficulty.

MISCELLANEOUS PREVENTIVE METHODS FOR GRAIN TREATMENT

Copper carbonate dust is sometimes used on seed wheat in storage to prevent the carrying over of disease spores on the seed. The dust also prevents insect damage. Dusted grain may be safely held for planting the second season. Copper carbonate is applied to wheat at the rate of two ounces per bushel. It should **not** be applied to grain intended for animal or human consumption.

Seed corn is said to be effectively protected from insect injury by dipping the ears in oil emulsions and miscible oils such as are used for spraying fruit trees. The emulsions are diluted one part to ten parts of water.

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Mackie, W. W. Prevention of insect attack on stored grain. Univ. of Calif. Circ. 282. Revised 1930.

STORING CEREALS AND OTHER FOOD PRODUCTS

Methods of storing cereals and cereal products in order to protect them from insect attack are: low temperature, low moisture content, and air-tight storage. Low temperature or cold storage is the oldest and most common method. Experiments have shown that there is very little insect activity at 45 degrees F. and that nearly all insects are

dormant at 43 degrees. Therefore a temperature of 40 or 43 degrees F. is all that is necessary. A lower temperature involves needless expense.

Recent work tends to show that few insects can live in cereal products whose moisture content is 20 per cent below normal. While it is necessary to reserve specific recommendations with regard to dry storage, when cold storage is impossible it is of the greatest importance to watch the moisture content of the products placed in storage. If the percentage of moisture is high, it is advisable not to attempt long storage in summer.

Air-tight storage for the prevention of insect attack in cereal products is a recent development. It is hardly beyond the experimental stage, but the results obtained experimentally in England indicate that it might be applied to large-scale storage. Insects can not live without a certain amount of oxygen, and carbon dioxide is poisonous to them. Since both the weevils and the wheat consume oxygen and give off carbon dioxide, it is only a matter of time until the atmosphere in the granary will kill the insects. As there is about 38 per cent of air even where the wheat is packed tightly, it is still an open question as to how long the insects may live. It is known that the beetles are killed more quickly when the wheat is moist than when it is dry.

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