5 Biology, Behavior, and Ecology of Pests in Other Durable Commodities

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Introduction

Other durable commodities of economic importance besides dry grains include tobacco, spices, mushrooms, seeds, dried plants, horticultural and agronomic seeds, decorative dried plants, birdseed, dry pet foods, and animal products such as dried meat and fish, fishmeal, horns, and hooves. Similar to dry grains, these commodities are typically maintained at such low moisture levels that preserving quality by minimizing insect damage can be a significant challenge. Stored commodities may become infested at the processing plant or warehouse, in transit, at the store, or at home. Many arthropod pests of stored commodities are relatively abundant outdoors, but natural host plants before preadaptation to stored products remain unknown. Capable of long flight, they migrate into unprotected warehouses. Adults (larvae) crawl through seams and folds or chew into sealed packages and multiply, diminishing product quality and quantity. Infestations may spread within a manufacturing facility through electrical conduit and control panels.

The type of pest observed on a stored product depends on the commodity, but some insects vary widely in their food preferences and may infest a wide range of commodities. Not all insects feed on the product. Some might be predators or parasitoids of feeding insects or other incidental insects. These are likely temporary invaders, scavengers that feed on animal and plant by-products, materials discarded or stored by animals, items kept in warehouses, or materials that accumulate in processing facility equipment and structures. This chapter reviews the biology, behavior, and ecology of the common insect pests of stored durable commodities. Physical elements defined by the type of storage structure, insect fauna, and interrelationships in the storage environment are also discussed.

Life Histories and Behavior

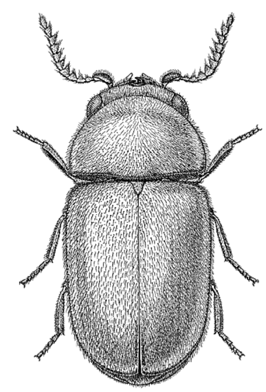

Figure 1. *Adult of the cigarette beetle, Lasioderma serricorne (F.), 2 to 4 mm long (from Bousquet 1990).*

Cigarette Beetle *Lasioderma Serricorne* (F.)

The adult is 2 to 3 mm long, 1.25 to 1.5 mm wide, and light to dark brown. Antennae are sawlike and have the same thickness from the base to the tip. The head is withdrawn under the insect when the insect is at rest or dead, giving the insect a characteristic humped appearance. When disturbed, the beetle feigns death, drawing body regions closely together for a few minutes. Adults cut holes to penetrate or escape from packaged commodities but rarely feed. Larvae cause most feeding damage observed in infested commodities. *Lasioderma serricorne* is a good flier. It is active at dusk and remains so until midnight. Although capable of long flight, beetles usually are distributed through the sale of infested materials.

Climate determines the number of *L. serricorne* generations occurring per year. The insect is active throughout the year in warm buildings in temperate and subtropical regions. Development slows during the winter. In the United States, *L. serricorne* seasonal flight activity starts in late March to late May, depending on location. The life cycle of the cigarette beetle includes egg, larva, pupa, and adult stages.

When laid, the oval-shaped egg is opaque or white, turning dull yellow shortly before hatching. The female deposits eggs singly in crevices or folds within the commodity. On average, *L. serricorne* progresses through four larval instars. Larvae are scarabaeiform in shape, i.e., when at rest, bodies curl into a "c" shape. When fully grown, the larva stops feeding and builds a cocoon in a spot that provides a firm cell foundation. Uniformly white at first, the pupa gradually assumes a reddish brown color, darkening with age. Males and females look similar from the outside. Sexes differ at the tip of the pupae abdomen, which can be seen after molted skin is removed.

Temperature and humidity affect development. Optimum conditions are 32˚C and 75% relative humidity (RH). Beetle development is impaired below 40% RH or above 90%, or at temperatures above 36˚C. *Lasioderma serricorne* development is also affected by type of food on which the insect is reared. Under optimum conditions, it takes about 68 days for the insect to develop from egg to adult emergence on oriental tobacco; development is about 20 days less when the beetle is reared on yeast cake or a mixture of wheat flour plus yeast.

Pheromone plays an important role in the reproduction biology of *L. serricorne* by bringing both sexes together and exciting them to copulate. Seven components of the sex pheromone released by female *L. serricorne* have been identified (Chuma et al. 1985). Serricornin is the compound that elicits the strongest attraction and sexual activity in the male *L. serricorne*. Six other pheromone compounds are regarded as minor components, i.e., are less attractive to male beetles, and produced by the female in relatively lower quantities.

Commercial pheromone lure for *L. serricorne* typically consists only of serricornin. Because serricornin only captures male cigarette beetles, food attractants with synthetic serricornin that attract both females and males are being marketed to improve trap efficiency. Because of the overwhelming tobacco volatiles in the environment, additional studies are needed to determine the efficacy of the food lure in a tobacco warehouse or manufacturing facility. To be effective, pheromone lures must be changed regularly following manufacturer's recommendations.

Important natural enemies (arthropods and bacteria) recorded as attacking the cigarette beetle in storage are reviewed below.

Commodities infested – Although the name "cigarette beetle" conveys the impression that *L. serricorne* confines feeding activities to manufactured tobacco (cigarettes), the insect feeds on all cured tobacco products. The cigarette beetle probably has the most varied taste of all storage insects. Besides tobacco, the insect feeds on a wide range of dried substrates of animal or vegetable origin. Substrates that have been reported as breeding materials or food for *L. serricorne* include tobacco seed, dried figs, dried roots of various kinds, pressed yeast, dried dates, starch, bran, belladonna, dried fish, pyrethrum powder, dried cotton, cotton seed, dog food, almonds, furniture stuffing, and bookbinders' paste (Runner 1919; Howe 1957; Singh et al. 1977; Yokoyama and Mackey 1987). The cigarette beetle is also a major pest of several dried spices and herbs (Table 1), and of dried plants in botanical collections. The common food for the cigarette beetle is cured or manufactured tobacco. On tobacco, the insect prefers leaves with low nicotine and high sugar content. Beetle development is impaired on tobacco diet containing more than 8% nicotine (Milne 1963).

Lasioderma serricorne harbors the intracellular yeasts *Synbiotaphrium buchneri* or *S. kochii* or *Crytococcus albidus* in specialized tissues (mycetomes) at the junction of the foregut and midgut of the insect (Jurzitza 1979; Ryan 2001). These intracellular yeasts synthesize essential amino acids, vitamins, and sterol and enable the insect to feed on food items of relatively poor nutritional quality (Pant and Fraenkel 1950; Milne 1963). Symbionts are transmitted to the next generation superficially on the eggs. Larvae acquire them by eating the eggshells upon hatching.

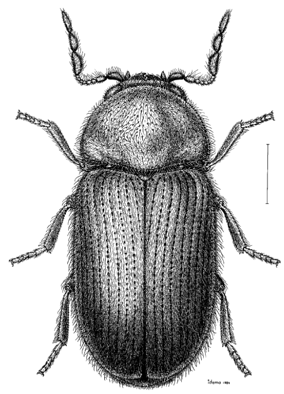

Figure 2. *Adult of the drugstore beetle, Stegobium paniceum (L.), 2-5 mm long (from Bousquet 1990).*

Drugstore Beetle *Stegobium Paniceum* (L.).

The drugstore beetle *Stegobium paniceum* (L.) (Figure 2) are uniform brown to reddish, cylindrical in shape, and between 2.5 and 3.5 mm long. *Stegobium paniceum* is virtually cosmopolitan, but its distribution is more temperate than tropical (Lefkovitch 1967). The insect received its Latin name from its occurrence in dry bread (*panis*). In Europe, it is still known as the bread or biscuit beetle. *Stegobium paniceum* attacks many pharmaceutical products and medicinal plants, from which the beetle got its common name.

Beetles are usually distributed in infested materials distributed in commerce. *Stegobium paniceum* is the only other anobiid beetle to be a serious pest of stored products, and the adults of the beetle are similar in appearance to the cigarette beetle. *S. paniceum* can be distinguished from *L. serricorne* by two physical characteristics. The antennae of *L. serricorne* are serrated, while in the *S. paniceum*, the last three segments of the antennae form a large loosely segmented club. The other difference is that the elytra of *S. paniceum* have longitudinal rows of pits giving them a striated (lined) appearance, while those of *L. serricorne* are smooth. The larvae of *S. paniceum* are also similar to cigarette beetle larvae, but the former have shorter hairs and the head marking ends in a straight line across the frons just above the mouthparts. The larvae typically assume a curved position when feeding in their burrows. The pupa is also similar in shape to the cigarette beetle, but proportionally much more slender. Four or five generations may occur in a year in warmer climates or heated buildings in temperate countries.

Although both sexes of *S. paniceum* are similar in appearance, the male can be distinguished from female beetles by a slot-like structure that is discernible on the tarsal claws of males but absent in females (Ward and Humphries 1977). This diagnostic characteristic is discernible only in specimens mounted on a slide. Similar to the cigarette beetle, *S. paniceum* life stages are comprised of the egg, larva, pupa, and adult stage. The female is capable of laying up 75 eggs in a lifetime at 23°C and 65% RH (Lefkovitch 1967). The female drugstore beetle lays eggs singly in foodstuffs, and about 80% of eggs laid by mated females are fertile. Development of the beetles is possible at temperatures between 15 and 35°C and 30% RH and above. Optimum conditions for rapid development are 30°C and 60 to 90% RH (Lefkovitch, 1967. The development from egg to adult emergence is completed in about 40 days at optimum conditions for rapid development (30°C and 60 to 90% RH). Adult longevity is about 85 days at 17.5°C and 50 to 70% RH.

Similar to cigarette beetles, females of *Stegobium paniceum* (L.) produce a sex pheromone that attracts males. The sex pheromone consists of the two compounds: stegobinone and stegobiol (Kodama et al. 1987a; Kodama et al. 1987b). Stegobinone is the major component and the one primarily used in commercially available traps and lures. The sex pheromones of another anobiid, *Anobium punctatum* De Geer, the furniture beetle, may consist of the same isomer of stegobinone and are attractive to *S. paniceum* (White and Birch 1987). Traps baited with these compounds can be used to monitor both pest species. According to Haines et al. (1991), the natural enemies of *S. paniceum* are much the same as for the cigarette beetle.

Commodities infested – Damage due to *S. paniceum* is typically done by the larval stages. Adults might chew through packaging when they emerge from infested commodities, leaving large, round holes (Lefkovitch and Currie 1967). True to its name, *S. paniceum* feeds on herbal medicines and pharmaceuticals. The insect has been known to attack grain and grain products, spices and herbs, dried fruit, seeds, dried fish, bread, birdseed, dry dog and cat food, coffee beans, chocolate, powdered milk, and many other organic materials. It is a serious pest in museum specimens, dried spices and herbs, and has been reported to attack books, manuscripts, upholstery, and other food substrates. Similar to the cigarette beetle, *S. paniceum* can produce its own B vitamins with the aid of yeast-like organisms that it harbors at the junction of the fore- and mid-gut in structures known as mycetomes. This allows the insect to subsist on foods very low in vitamins of that group (Pant and Fraenkel 1950).

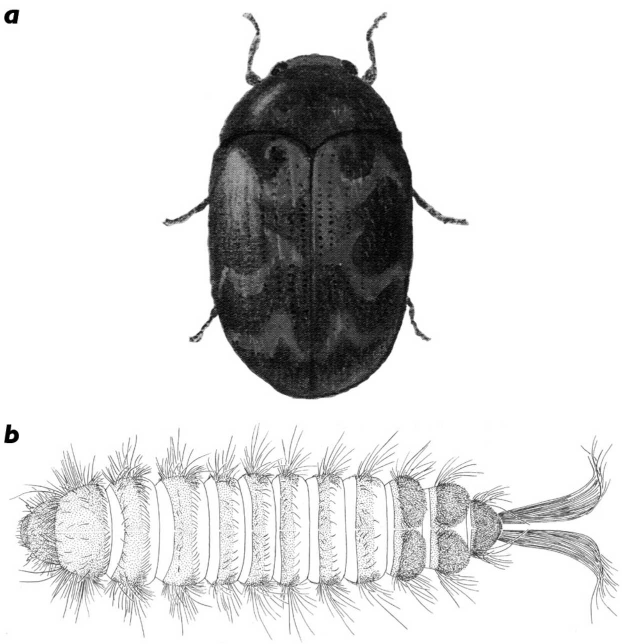

Figure 3. *Adult (a) and larva (b) of the warehouse beetle, Trogoderma variabile Ballion, 2.7 to 3.5 mm long (from Gorham 1991).*

Warehouse and other carpet beetles

Carpet beetles belong to the family of beetles known as dermestids. The beetles get their common name "carpet beetles" because they were once a common pest on woolen carpets. Although species in the family still feed on woolen items such as carpets, they are more commonly pests of fabrics, furs, stored foods, and preserved specimens and cause serious damage to these items. There are many species of carpet beetles. Those commonly found in homes, feed mill, and food manufacturing facilities belong to the genera *Anthrenus, Attagenus, Dermestes,* and *Trogoderma*. The life histories and habits of dermestid beetles differ significantly; therefore, correct identification is essential as a foundation for effective control procedures. Descriptions and keys to identification of adults and larvae of beetles in the family Dermestidae can be found in Rees (1943), and Beal (1960, 2003). This chapter will focus on *Trogoderma* spp, especially the warehouse beetle (*T. variabile*) and related species, because of the worldwide persistence of these beetles as pest of stored products, packaged goods, and handling facilities.

Adult *T. variabile* (Figure 3a) are small (about 3.5 mm in length), oval, and predominately black with dense, dark-brown scales or setae covering the elytra. Adult females of the warehouse beetle produce a pheromone that excites and attracts the males. Synthetic *T. variabile* pheromone is commercially available for use in traps for monitoring the insect. Larvae are about 6.3 mm in length; light brown and cylindrical, with tufts of dense hairs protruding from the last abdominal segment (Figure 3b). Dermestidae larvae are distinct from the larvae of other stored product beetles. The larvae appear "hairy" because of a combination of setae, heavier bristles, and fine and spear-shaped setae that can entangle other insect species. The life cycle of the warehouse beetle consists of the egg, larva, pupa, and adult stage. A female may lay up to 80 eggs in her lifetime under optimum conditions (about 30°C and 70% RH). Eggs are laid singly in the food source and develop to adulthood in about 30 to 45 days. *Trogoderma* species larvae can suspend development (diapause) for a long time if environmental conditions become unfavorable (e.g., low temperatures, crowding, and starvation). For example, trogoderma dermestid beetle *Trogoderma tarsale* Melsheimer was able to survive for more than five years without food (Wodsedalek1917). The survival of *Trogoderma* larvae through diapause makes eradication difficult.

The warehouse beetle and khapra beetle (*T. granarium*) share close physical similarities, but the later has a limited ability to fly, so beetles caught in flight traps where both species occur are likely to be warehouse beetles (Stibick 2007; USDA-APHIS 2011). Traps for monitoring *T. granarium* should be placed at or near ground level. Species confirmation is essential for insects not captured in flight traps if there is concern about *T. granarium* activity.

Trade and import issues often are a major concern, especially with khapra beetles. The insect is difficult to control because of its ability to survive for long periods without food, preference for dry conditions and low-moisture food, and resistance to most approved insecticides. A federal quarantine restricts the importation of certain commodities into the United States from countries with known infestations of khapra beetle.

Other species within the *Trogoderma* genus includes ornate carpet beetle (*T. ornatum*), larger cabinet beetle (*T. inclusum*), *T. sternale*, glabrous cabinet beetle (*T. glabrum*), and European larger cabinet beetle (*T. versicolor*). The warehouse beetle is similar in appearance to other *Trogoderma*, but diagnostic characteristics such as the the medial margin of the eye and the two-colored wing case (elytra) can be used to separate this species from the other *Trogoderma* species listed above except *T. sternale*. Unlike *T. sternale*, the basal and submedian bands of each elytron are not connected by a longitudinal band or bands, and male antennal clubs are not serrate (Bousquet 1990).

Adults and larvae of *Trogoderma* species are similar in appearance and may be difficult to distinguish by a nonspecialist. Adults of *Trogoderma* species should not be identified by color patterns alone as species may vary in their markings. Identification should be confirmed by examination of the eye margins, shape of antennal cavities, metasternum, and other features on the adult. Other features that may be used to distinguish between *Trogoderma* species include antennae, abdominal sutures, and placement of hastisetae.

Commodities infested – Similar to other economically important families, the majority of damage by dermestid beetles occurs while the insects are in the larval stage. Unlike other stored product beetles, e.g., red flour beetles (*Tribolium castaneum* Herbest) and lesser grain borer (*R. dominica*), that can survive on grain kernels or flour alone; dermestid beetles have a variety of habits. Most genera are scavengers that feed on dry animal or plant material such as skin or pollen, animal hair, feathers, dead insects, and natural fibers. The larvae feed upon, damage, or destroy household furnishings, and various materials made of leather, hair, fur, wool, and silk, dried animal remains, museum specimens and exhibits, and insect collections. The larvae are also an important pest of durable commodities, including bacon, cheese, cork, seeds, cereals, and cereal products (Rees 1948). They have been detected around mills, especially in areas where flour, other insect infestations, and mold abound. With bakery mixes (cake mixes), the insect will more often be found in the ingredient, but can be quite prevalent in the mixture of flour, yeast and dried egg. Similar patterns have been observed in processing plants producing dry pet food. The beetles will be found toward the end of the processing line, particularly between cooking and drying and the packaging line. Besides causing damage to stored product due to feeding activities, the setae (hairs) of *Trogoderma* larvae and other dermestid beetles are an important health hazard. The setae are shed within the food product infested by the larvae and are present on larval cast-off skins after molt. Ingestion of food contaminated with larval cast skin may lead to gastric irritation and symptoms of similar to food-borne illness. Severe sensitivity to larval caste skins can lead to respiratory distress and conjunctivitis and has been attributed to cleaning equipment infested with warehouse beetles (Bernstein et al. 2009). Health risks may not only force disposal of products and ingredients, but can also lead to more serious liability and brand security issues.

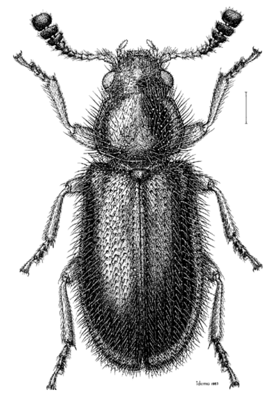

Figure 4. *Adult of the redlegged ham beetle, Necrobia rufipes De Geer, 3.5 to 4.5 mm long (from Bousquet 1990).*

Redlegged Ham Beetle, *Necrobia rufipes* DeGeer

The redlegged ham beetle is a member of the beetle family, Cleridae. Commonly known as checkered beetles, they are typically predators and scavengers of other insects in nature. *Necrobia rufipes* is adapted to feeding on dried meats, such as southern dry-cured hams and fish meal (Hasan and Phillips 2010). The beetle likely became adapted to human-stored animal products from wild ancestors that were scavengers on vertebrate carrion and other dried animal carcasses. Although scavenging and feeding on dead animal or insect tissues is common, *N. rufipes* has been observed to cannibalize its own live eggs and larvae and to actively prey on other arthropod species in its stored meat or cheese habitat such as various life stages of the cheese skipper moth, *Piophila casei*, and immature of the hide beetle, *Dermestes maculatus* (Arbogast 1991).

Adults of the redlegged ham beetle (Figure 4) are approximately 5 mm in length, even-sided with clubbed antenna, pale yellowish to reddish colored legs, and a dark blue to metallic green body color. Larvae hatch from eggs laid on the surface of food, and then burrow into the food material. Mature larvae spin cocoons in which they pupate, usually in crevices between foods or in other ways isolated from other late larvae. Development from egg to adult takes about 25 days at 30°C. *Necrobia rufipes* has a cosmopolitan distribution, and is commonly found in association with *Dermestes* beetles. Pheromones have not been described for *N. rufipes*, though it may be found in traps used for other beetles, perhaps orienting to odors of food from the grain-based oils in such traps (Roesli et al. 2003). Arthropod natural enemies for *N. rufipes* have not been studied, and considering their ecological status as a predator, it is unlikely that parasitoids are commonly associated with it. Co-occurring predators and scavengers utilizing the same food resources will have some impact on eggs and other immature stages of *N. rufipes*. The impact of these is unknown though suspected to be minimal.

Commodities infested – The redlegged ham beetle is the most important of a group of arthropods that infest meats that are dried to some extent by evaporation during long-term ambient temperature storage, usually following infusion with salt solutions or smoking. It is also one of the most destructive pests of coconut meat, referred to as copra. In addition, *N. rufipes* has been found feeding on a wide variety of animal-derived foods including cheese, ham, bacon, fish, salt fish, bones, bone meal, drying carrion, as well as dried figs, palm nut kernels, and guano (Arbogast 1991). Species in the genus *Necrobia* can develop on dead fatty animal matter, sometimes on oily plant substances, or on larvae of other carrion visitors. Because of these feeding habits, *N. rufipes* can be useful in estimating the forensic status and the post-mortem interval on human cadavers. *Necrobia rufipes* has also been found associated with Egyptian mummies (reviewed in Hasan and Phillips 2010). *Necrobia rufipes* is one of the predominant pests, and a major target of pest control efforts, among arthropods infesting southern dry-cured hams in North America.

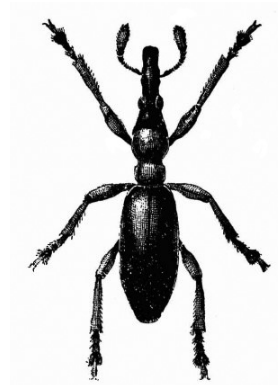

Figure 5. *The adult of the sweetpotato weevil, Cylas formicarius (F.), 6 to 8.5 mm long (from Sherman and Tamashiro 1954).*

Sweetpotato weevil, *Cylas formicarius* (F.)

The sweetpotato weevil, *Cylas formicarius* (F.) (Figure 5), is a beetle in the family of weevils that have an elongated snout, the end of which is equipped with mouthparts. The sweetpotato weevil is particularly striking in that it looks like an ant, with the antennae, thorax, and legs orange to reddish brown, a black head, and the abdomen and elytra being metallic blue. It is presumed to have evolved as an ant mimic to avoid predation. *Cylas formicarius* is a serious pest of sweet potatoes, *Ipomoea batatas*, as they mature in the field and then during storage. The pest was apparently introduced into United States from Central America or the Caribbean in the late 19^{th} century and is now established in the southeastern United States north to North Carolina and west to Texas. Female sweetpotato weevils lay single eggs into cavities, which chew in stems or tubers, and then cover the egg with a sort of fecal plug. Eggs hatch in about 6 days and the grub-like larvae tunnel in the tuber material, leaving frass in the tunnels behind them, which is the main activity of their damage to the sweet potato. There are three larval instars taking a total of about 40 days to develop, after that, the pupa develops for 7 to 10 days inside a chamber constructed by the mature larva. Adults chew a round emergence hole to the outside of the tuber and can live up to 200 days, fly very little, are active mostly at night, and become reproductively mature within days of emergence (Capinera 2009).

Cylas formicarius utilizes a female-produced sex pheromone that has been identified, synthesized, and is available commercially in lures for monitoring pest populations with traps and potentially for population manipulation via mating disruption (Jansson et al. 1991). In addition to the weevil causing serious post-harvest losses to sweet potatoes, it also represents a quarantine risk if infested sweet potatoes were to be exported from the United States to countries that do not yet have *C. formicarius* established within their borders.

Some species of parasitoid wasps have been reported emerging from sweetpotato weevil larvae collected in the southeastern United States, but no systematic studies have investigated the potential for these natural enemies to be used in biological control.

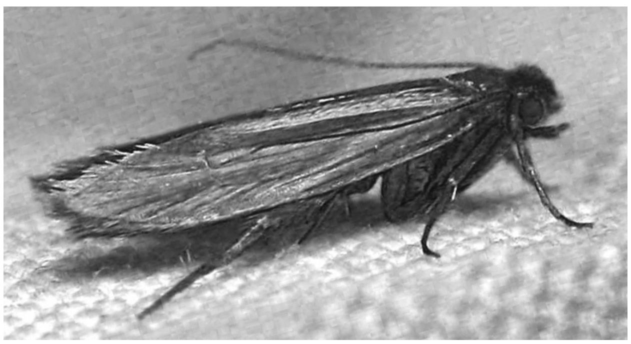

***Figure 6.** The adult of the webbing clothes moth, Tineola bisselliella (Hummel), 5 mm long (P. Kelley, Insects Limited).*

Clothes moths

The moth family Tineidae contains several species referred to as cloths moths because they are pests of fabrics made from natural animal-derived fibers. In fact, clothes moths such as the webbing clothes moth, *Tineola biselliella,* and the case-making clothes moth, *Tinea pellionella* (Figure 6) require a diet of wholly or mostly animal products for larval development. Although dried meats, egg, and dairy products can be utilized, these moths prefer fibers from the skin and hair of vertebrates such as wool of sheep, furs from numerous mammals, bird feathers and dried skin of all kinds. Silk generated from the silk moth, *Bombyx mori*, can also support growth and development of clothes moths. Adult clothes moths are small, buff-colored moths with a body length of 5 mm or less. Larvae generate silk while feeding. The larvae of *Tinea* make a silken case that they reside in, feed from, and carry with them, much like the shell of a snail. Development of clothes moths from egg to adult may take 40 days at 25˚C (Rees 2004).

The pheromone biology of clothes moths is not like other moths, as both males and females produce attractants that facilitate mate finding at oviposition resources. These pheromones have been partially identified and are available for commercial use, but pheromone-based monitoring of clothes moths has not achieved the level of adoption of that with typical food moths such as *Plodia* and *Ephestia*. Parasitoid wasps are known from clothes moths, but none have been researched in depth or developed for commercial biological control.

The significance of clothes moths is relatively minor when considering all stored product pests, but for certain high value animal products, such as hand-woven wool carpets, expensive silk clothing, and valuable museum artifacts of animal origin (e.g., aboriginal furs or skins), clothes moths represent serious pests for which 100% control or prevention must be achieved.

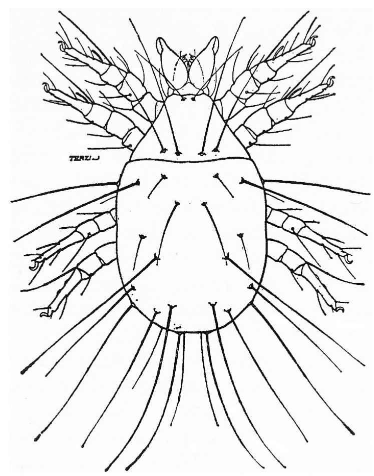

***Figure 7.** The mold mite, Tyrophagus putrescentiae (Schrank) (Source: USDA), 280 to 350 microns long (from Evans et al. 1961)*

Mold mite, *Tyrophagus putrescentiae,* Schrank

Tyrophagus putrescentiae (Schrank) (Figure 7) is one of the astigmatid mites, a group of soil-dwelling mites in the family Acaridae. The mites can be found in homes and buildings, which they invade via various insects and vertebrate hosts that have used mite-infested nests, or via movement of infested food, plant, and animal material to new locations. Structures or processing machinery may also harbor hidden infestations that contaminate product during manufacture before transportation to other sites. *Tyrophagus putrescentiae* is widely distributed throughout the world. Together with the related species *T. longior*, it is commonly referred to as the mold mite. Currently, the genus *Tyrophagus* comprises about 35 species and is worldwide in distribution. The mold mite is often mistaken for the grain mite (*Acarus siro*), or a variety of other mite genera and species, including *Tyrophagus* mites such as the cheese mite (*Tyrophagus casei*). Mite identification usually stops when the observer sees small eight-legged creatures. In the durable commodities market, species identification beyond the simple determination of "mite" is critical when attempting to determine the infestation source, leading to effective prevention and control steps against an infestation. Description and keys for identification of mite species, including storage mites can be found in Robertson (1959), Smiley (1987), and Kucerová and Stejskal (2009).

Adult mold mites are small, measuring about 0.3 mm long. In most cases, bodies lack segmentation and segmented somites. Their small size makes early infestation by mites difficult to detect and enables them to enter packaging and exploit food residues in very small cracks and crevices.

Females may lay up to 488 eggs during a lifetime. Population doubling may occur in as little as 2 to 4 days (Sánchez-Ramos et al. 2007). Under ideal conditions, 100 mites can render about 100 g of dog food to dust in less than 4 weeks. The life cycle consists of the egg, larva, protonymph, tritonymph, and adult stages. The larvae have six legs, but the juveniles (protonymph, tritonymph) have four sets of legs like adult mites. The adults and juveniles are oval, cream, and milky- or white-translucent. Development from the egg to adult takes about 1 to 3 weeks, and could take 118 days depending on environmental conditions and the food type on which the mite is reared (Kheradmand et al. 2007).

As indicated, infestations by mold mites are very common but are often difficult to detect except in occasions of severe infestations. Usually the first sign of an abundant infestation is the presence of a rapid accumulation of dust, which is made up of biomass from live and dead mites, mite eggs, frass, and food particles on or around a food product. The presence of dust suggests the likelihood of a major infestation in the adjacent area and fragmented smaller populations in adjacent areas. Mites tend to undergo rapid dispersal when conditions become unfavorable from overcrowding, food depletion, or degradation. The trigger for this dispersal has been attributed to the release of an alarm pheromone, neryl formate (Kuwahara et al. 1975), but the mechanism involved the dispersal process is not fully understood. Dispersal may also result from movement of contaminated foodstuffs, equipment, plant, and animal material to new locations

The original food of *T. putrescentiae* is believed to be fungi. Consequently, they would appear to be preadapted to feed on a wide range of stored food and feedstuffs and many other commodities of plant and animal origin (Hughes 1976). Although the name "mold mite" conveys the impression that *T. putrescentiae* confines its feeding activities to mold, *T. putrescentiae* infest a wide range of stored products with relatively high protein and fat contents, and can be found in decaying organic matter, plant seeds, medicinal plants, and mushroom beds (Kheradmand et al. 2007). *Tyrophagus putrescentiae* also feeds on different fungi including molds (e.g., Bahrami et al. 2007) and a number of dermatophytes and yeasts (Duek et al. 2001). The mite also has been reported to feed on nematodes and other microorganisms in culture (reviewed in Bilgrami and Tahseen 1992). The common name mold mite has led to some confusion when untrained persons are trying to determine the sources of this mite. Often there have been mistaken references to food being moldy, hence the presence of this mite. This has led to considerable confusion, particularly when infested food contains preservatives or fungistats. The role of fungi in the nutritional ecology of *T. putrescentiae* is yet to be fully understood. For example, although the presence of molds has been shown to encourage growth and development of *T. putrescentiae*, the mite would develop well on susceptible foods that are free from mold infestation (Canfield and Wrenn 2010). Mold may be required as a direct food source, or as a commensal organism providing essential nutrients or moisture to the mite in nutritionally poor foods. Mold may be a competitor for existing resources or a simple opportunist when mites begin to invade a food source. Mold and mites may coexist in an area because both types of organisms have similar favorable environmental conditions. For such a simple creature, nutritional requirements and relationships to mold and fungi may be complex and require further study.

The main ecological factors affecting the growth and development of mites are temperature, food sources, and in particular, the relative humidity of the microenvironment (Sánchez-Ramos et al. 2007). *T. putrescentiae* is particularly susceptible to low humidity because its relatively weakly sclerotized cuticle could cause the mite to desiccate at low humidities. The optimal humidity for survival appears to be 90% (Kheradmand et al. 2007). Growth and development of *T. putrescentiae* might cease at extended relative humidity below 65%. As humidity begins to decrease from optimal, mites may cluster together to reduce the impact of water vapor stress (Cutcher 1973), or may to a limited extent, rely on structures called supracoxal glands to maintain water balance through water absorption (Arlian 1992; Wharton et al.1979). Key techniques suggested for integration for management of *T. putrescentiae* includes humidity management, sanitation, freezing, stock management, as well as use of phosphine fumigation (Nayak 2006; Eaton and Kells 2009; 2011).

Commodities infested – *Tyrophagus putrescentiae* is a cosmopolitan stored product pest of significant economic and health importance. The mite infests stored products with relatively high protein and fat content such as wheat and soy flour, herring meal, bacon, cheese, dried milk, dried meats, nuts and grains, fruit, mushrooms, various seeds, and dry dog food (Robertson 1952; Hughes 1976; Arnau and Guerrero 1994; Duek et al. 2001, Kheradmand et al. 2007; Brazis et al. 2008). Fang and Zhang (2007) provide an extensive list of cases where this mite was found in plants, soil, and flowers, and this mite has been found associated with agricultural soils. Even products that would not seem to fit the above criteria, such as dried pasta, can be susceptible if storage conditions are cool and damp.

Tyrophagus putrescentiae has been shown to attack the stored product insect *L. serricorne* (Papadopoulou 2006), and to be an effective eggs predator of the field pest southern corn rootworm, *Diabrotica undecimpunctata* Howard (Brust and House 1988). The mite also has been recorded to predate on nematodes such as *Meloidogyne javanica* (Treub), and *Aphelenchus avenae* Bastin (Bahrami et al. 2007; Kheradmand et al. 2007). Although *T. putrescentiae* has been associated with beehives, its presence and significance is not fully understood. Besides damage to stored products and predation on other insects, *T. putrescentiae* is considered an important species in health and medicine. The mite produces allergies that induce discomfort conditions in human skin and breathing. For example, the predominant allergic mite in dust and debris samples from several coalmines was found to be *T. putrescentiae* (Solarz and Solarz 1996).

Monitoring and control of mite-prone areas is a method of affecting sources of mite infestations before they have a chance to move onto food product. Specifically, reducing the number of refugia and increasing the distance between other mite sources and susceptible food product can help prevent infestations. Three methods of monitoring mites include the use of baited mite traps, equipment or product sampling, and vacuum sampling. Baited mite traps have a food item and suitable humidity that attract mites to the container. The traps will collect mites over 24 hours, though the trapping period may be longer depending on humidity and bait consistency. These traps collect mites that have moved out of the refugia and rely on mite dispersal behavior.

Equipment or line sampling are more active practices used in food processing plants to determine if mites are harboring in the processing equipment. For equipment sampling, swab samples of food residues are taken from key areas of the processing equipment. Usually these areas exist after thermal or pressure processing steps and may include dust collection fittings, dead spaces, and areas where product flow changes direction or decreases in velocity. Equipment samples are evaluated under a microscope. Finished product samples (or line samples) are packages of product removed from the line, and inspected for mites or incubated for a period before inspection.

Vacuum samples utilize a method adapted from sampling for dust mites, using equipment set up to be used in an industrial environment. A filter of 193 x 193 nylon meshes is placed in a vacuum hose, and surfaces, cracks and crevices, and pallets can be vacuumed. Each vacuum sample covers an approximate area of 30 cm x 4 cm. Filters are inspected visually. The advantage of this sampling method is that possible refugia sites can be sampled directly. This sampling method can be used to prioritize sanitation and exclusion techniques because areas yielding mites can be directly targeted for remediation. The type of monitoring method used and the number of samples taken will depend on the susceptibility of the food product and how favorable the habitat is for mites.

Storage Ecosystems by Commodity

Tobacco

Tobacco packaging and storage

The cigarette beetle does not attack growing tobacco and is not present in tobacco fields. The insect prefers cured tobacco, thus infestation by *L. serricorne* is of major concern to tobacco manufacturers rather than the growers, as the latter are less likely to hold stock longer than necessary. To improve aroma, taste, and other quality characteristics, cured tobaccos are held in storage for 1 to 2 years or more to allow for slow fermentation, or aging of the leaves under natural conditions of temperature and humidities. As a result, manufacturers often carry in storage large stocks of tobaccos in order to fulfill manufacturing requirements. Tobaccos of different crop years are often stored in the same warehouse because it is economically difficult to keep stocks in storage by crop years. Within warehouses, tobacco stored in the same lot is typically grouped together into an aisle to facilitate movement of equipment, sanitation, and related pest management activities.

In the United States, hogshead is a major container for holding tobacco while it is transported, stored, or aged. Hogshead is made from wooden staves joined together with metal and wire hoops to form a closely fitted barrel-shaped container. Between two hogshead staves are cracks measuring about 6.5 mm (Reed et al. 1941). One hogshead can hold up to 500 kg of tobacco. Cardboard boxes and bales are other packaging containers that serve the same purpose as hogsheads. A cardboard box may hold 200 or 500 kg of cured tobacco. To make a bale, cured tobacco is placed in layers in a wooden crate atop a scale that has been lined with burlap or nylon. When the desired weight (usually 30 or 50 kg) has been achieved, the tobacco is compressed into a rectangular a block. The sides of the bales are stitched together and the wooden supports removed, revealing the bale. Packages offer limited barrier to entry by stored tobacco pests. Hogshead packing is vulnerable because beetles can easily migrate into the container through the cracks between the wooden staves.

Before the mid 1970s, much of the tobacco aged in the United States was stored in open or semi-closed warehouses that are merely sheds with open or partly open sides. The objective of these early designs was to maintain good air circulation and even temperatures throughout the warehouse. Controlling insects in these structures was often difficult. Tobacco warehouses became less open in the early 1970s due to the adoption of phosphine fumigation and improved leaf moisture content uniformity at packaging made possible with tobacco re-drying technology. Although the primary objective of tobacco re-drying is to facilitate processing of tobacco to manufacturer's grade, size, and moisture specifications, tobacco agitations and high temperatures employed during processing are sufficient to destroy all beetle stages before the leaves are packed in containers for storage (Tenhet and Bare 1951). Newly packed tobacco can become infested if containers are stored in an infested building or containers. Cigarette beetles are strong fliers, capable of using plant volatiles to locate potential food resources. In addition, female beetles release sex pheromones that attract the male for mating, building up pest populations in the warehouse or manufacturing facility. Contemporary tobacco warehouses in the Unites States are simple in design and vary in volume from 8,500 to 57,000 cubic meters. A major design requirement is the ability to close and seal the buildings for fumigation (USDA 1971; Ryan 1999).

Insects associated with tobacco storages

Several insect species may be found in tobacco warehouses, but very few actually feed on cured tobacco. Economically important stored product species such as *Sitophilus oryzae* (L.), *Tribolium* spp, and *Oryzaephilus surinamensis* (L.), etc., which feed on plant material and are found in tobacco storage structures, are of little importance as pests of cured tobacco, and may be regarded accidental invaders (Chittenden 1897; USDA 1971). Others such as the Tenebrionidae and Dermestidae are largely scavengers that feed on pollens and dried plant and animal matter, including dead insects. *Trogoderma variabile* Ballion, the warehouse beetle, has been observed to cause significant damage to cigarettes. The inability of many stored product insects to survive on cured tobacco may be due to the poor nutritional content of tobacco leaves relative to other stored products such as grains, or because of the substantial nicotine and other alkaloids content of leaf tobacco. Apparently, tobacco-feeding insects are able to tolerate or detoxify these chemicals in order to survive (Self et al. 1964; Snyder et al. 1993). In addition to nutritional contributions previously mentioned, *L. serricorne* symbionts are capable of assisting the survival of the host by detoxifying ingested xenobiotic to less harmful alkaloids, which the insects then excrete (Milne 1963). *Lasioderma serricorne* is also capable of excreting most of the nicotine ingested in the form ingested, i.e., unmodified, by the insect (Farnham et al. 2006), but the mechanism for achieving this is not fully understood.

Besides, *L. serricorne*, another insect that feeds on cured tobacco is the tobacco moth *Ephestia elutella* (Hubner) (Lepidoptera: Pyralidae). Although the insect is rarely encountered in tobacco storage in the United States, it is a serious pest of stored tobacco in cool temperate zones as far north as southern Canada (USDA 1971). Unlike *L. serricorne*, *E. elutella* does not attack manufactured products (Tenhet and Bare, 1951). The moth prefers tobaccos that are high in sugar and low in content, and rarely feeds on air- or fire-cured tobacco, or cigar types of tobacco (Tenhet and Bare 1951; USDA 1971). Other preferred food substrates of *E. elutella* are cacao beans, stored grains including peanuts, rice, etc., and their manufactured products. Life history and seasonal occurrence of *E. elutella* were described in early works (e.g., Tenhet and Bare 1951; Ashworth 1993).

Other insects that can feed on dried tobacco, especially in the subtropical and tropical regions, include the anobiid beetle called the larger tobacco beetle *Tricorynus tabaci* (Guerin-Meneville). *Tricorynus tabaci* has been recorded in Texas and Florida, and is occasionally intercepted in commerce (White 1971). The insect attacks cured tobacco in much the same way as *L. serricorne*, and feeds on tobacco seeds (USDA 1971; Runner 1919). *Tricorynus tabaci* is identical to *L. serricorne*, but the former is larger and black instead of brown. Another member of the genus *Tricorynus confusus* (Fall) has also been caught in tobacco warehouses in North Carolina and Virginia (White, 1971). *Tricorynus tabaci* can be distinguished from *T. confusus* by body length. The body length of *T. tabaci* varies from 3.4 to 4.6 mm long, while those of *T. confusus* vary from 1.8 to 2.6 mm long (White 1971). In addition, lateral striae are present on the elytra of *T. tabaci*, but are absent on those of *T. confusus* (White 1971).

Another insect that feeds on dried tobacco is the pyralid moth *Tulsa finitella* Walker (Tenhet and Bare 1951), but no information is available on the biology or feeding damage caused by this insect. The booklouse, *Liposcelis entomophila* (Enderlein) has been reported to occasionally cause economic damage to tobaccos in farm tobacco storages and grading buildings by feeding on leaf lamina (Mashaya 1999). Other insects, including *Mezium americamum* Laporte (Coleoptera: Ptinidae), infest tobacco seeds (Runner 1919).

A number of natural enemies attack *L. serricorne.* The pteromalid wasps *Anisopteromalus calandrae* (Howard) and *Lariophagus distinguendus* (Forest.) are important larvae and pupae parasitoids of the beetle (Bare 1942). Other hymenoptera parasites include the pteromalids *Theocolax elegans* (Westwood), the enrytomid *Brachophagus* sp., and the bethylid *Cephalonomia gallicola* (Ashmead) (Haines 1991). The predatory mites *Moniezella angusta* (Banks) and *Tyrophagus putrescentiae* (Schrank) feed on the larvae and pupae of *L. serricorne* (Bare 1942; Papadopoulou 2006). Another mite, *Blattisocius keegan* Fox, and the psocid *Liposcelis divinatorius* (Mull) have been reported to feed on *L. serricorne* eggs (Rao et al. 2002). Adult and larvae of the clerid beetle *Thaneroclerus girodi* Chevr are predaceous upon the larvae and pupae of *L. serricorne* (Morgan 1913).

These natural enemies have shown little practical importance in controlling populations of stored products insects, including *L. serricorne*, because the natural enemies are often at low numbers compared to their hosts, and the natural enemies only begin to suppress hosts after the hosts have reached quite high numbers (Edde 2012). The parasitoids and predators themselves fall prey to other organisms. Besides arthropods, the bacterium *Bacillus cereus,* a noncrystalliferous, aerobic, spore-forming bacterium that has been isolated from *L. serricorne* was found to cause significant mortality of *L. serricorne* larvae (Thompson and Fletcher 1972).

Spices and Herbs

The term “spices” refers to the flavored dried plant parts such as fruits, seeds, barks, and as bulb and rhizomes, while “herb” is used as a subset of spice, and is generally derived from fresh or dried leaves, and traded separately from the plant stems and leaf stalk (Peter 2001). Spices and herbs are used for flavoring, seasoning, preserving, and imparting aroma in food or beverages, and useful in the treatment of several disorders in humans because of their therapeutic properties. In this review, no distinction is made between spices and herbs. It is difficult to classify spices or herbs. For convenience, Ridley (1912) suggested that the crops might be grouped according to the parts of the plant that form the commercial product. For example, the flower bud is used in cloves; the fruit in nutmegs, vanilla, capsicums/pepper; the underground stems in ginger and turmeric; and tree bark in cumin and cassia. Spices are often dried and used in a processed but complete state, or may be prepared as extracts such as essential oils by distilling the raw spice material, or using solvents to extract oleoresins and other standardized products (Douglas et al. 2005). Important spice crops in world trade include pepper, nutmeg, cardamom, allspice, vanilla, cloves, ginger, cinnamon, turmeric, coriander, cumin, onion, paprika, saffron, sesame seeds, and the herbs sage, oregano, thyme, bay, and mints.

Packaging and storage requirements for species are as diverse as the range of plant species or plant parts from which the products are derived. For example, while dry onion, ginger, and turmeric for bulk storage are typically packed in jute or sisal sacks, wooden boxes, or lined corrugated cardboard boxes, others such as cinnamon and cassia, especially if ground, require polypropylene packaging (Douglas et al. 2005; Valenzuela 2011). Although freshly harvested spices and herbs have superior flavor compared with dried herbs, a greater proportion of the products are stored or marketed in dried form. It is essential that all material is dry to below 10% to prevent product deterioration and prolong shelf life.

The hygroscopic properties of many dried spices or herbs play an important part in the choice of packages or storage conditions. Popular packaging materials for dried spices and herbs include glass, metal, plastic and their derivatives, and elastomeric. These containers are impermeable, reducing the possibility of insect and moisture migration into the commodities.

The storage life of spices can be maximized if the products are harvested at the proper stage of maturity, cured properly, and are free of bruises, plant pathogens, and stored under relatively cool conditions. Storing at the right environmental conditions is essential to prevent pest damages to commodities harvested as bulbs and rhizomes. For example, the recommended storage conditions for ginger include temperatures of 12 to 13°C and 85 to 90% RH (Valenzuela 2011). Activity of most stored product insect pests is limited at temperatures below 15°C. Spices and herbs are able to keep storage insect pest damage to a minimum, especially when the crop has been dried to correct specifications and stored in temperature- and humidity-controlled conditions (Douglass et al. 2005). Pest damage to some spices and herb species might be limited by the repellant or inhibitory qualities of the aromatic oils and related alkaloids contained in the crops. When plants are stored on a commercial scale, some common stored-product insect pests do cause damage, especially if the crops are stored in inferior facilities and under less than ideal management. The most frequently occurring insect species found on spices are *L. serricorne* and *S. paniceum*. The biology and ecology of the two insects were reviewed earlier in the chapter. The feeding habits of the insects are similar, and as noted, the two beetle species harbor microorganisms that enable the insects to feed on plant species of diverse chemical compositions (Howe, 1957). Other important arthropod pest species besides *L. serricorne* and *S. paniceum* that have been recorded on stored spices and herbs are presented in Table 1. The list is by no means exhaustive. The reader may refer to work by other authors, e.g., Archibald and Chalmers (1983), Hagstrum and Subramanyam (2009), and USDA (1964) for additional information on the subject.

Table 1. *Insect species associated with spices and other seasonings (modified from Hagstrum and Subramanyam 2009).*

Insect	Spice/Herb
Aglossa ocellalis	ginger
Ahasverus advena	black pepper, chili pepper, coriander, ginger, nutmeg, onion, turmeric
Alphitobius diaperinus	coriander
Alphitobius laevigatus	onion
Alphitobius viator	chili pepper, ginger
Anthicus quisquilius	ginger
Anthrenus flavipes	black pepper
Anthrenus jordicus	onion
Anthrenus oceanicus	onion
Anthrenus verbasci	black pepper, chili pepper
Araecerus fasciculatus	chili pepper, ginger, ginseng root, nutmeg, onion
Attagenus cyphonoides	chili pepper
Attagenus fasciatus	coriander
Attagenus lobatus	chili pepper
Attagenus unicolor	black pepper, chili pepper
Bruchus rufimanus	saffron
Cadra cautella	allspice, chili pepper, ginger, nutmeg, onion
Callosobruchus analis	coriander
Callosobruchus chinensis	black pepper
Callosobruchus maculatus	black pepper, coriander, ginger
Callosobruchus phaseoli	coriander
Carpophilus brevipennis	garlic
Carpophilus dimidiatus	cinnamon, garlic, ginger, nutmeg, onion, turmeric
Carpophilus hemipterus	chili pepper, garlic ginger, onion
Carpophilus humeralis	onion
Carpophilus ligneus	garlic, ginger
Carpophilus lugubris	chili pepper
Carpophilus maculatus	chili pepper
Carpophilus marginellus	ginger
Carpophilus mutilatus	garlic
Carpophilus obsoletus	garlic, nutmeg, onion
Carpophilus pilosellus	garlic, onion
Cathartosilvanus vulgaris	chili pepper
Cathartus quadricollis	chili pepper
Caulophilus oryzae	ginger
Coccotrypes dactyliperda	nutmeg
Coccotrypes myristicae	nutmeg
Corcyra cephalonica	coriander, ginger, nutmeg
Cryptamorpha desjardinsi	chili pepper
Cryptolestes capensis	chili pepper
Cryptolestes cornutus	chili pepper
Cryptolestes divaricus	chili pepper
Cryptolestes ferrugineus	black pepper, chili pepper
Cryptolestes klapperichi	chili pepper, nutmeg
Cryptolestes pusilloides	anise, chili pepper
Cryptolestes pusillus	chili pepper, nutmeg
Cryptolestes turcicus	chili pepper, nutmeg
Dermestes ater	ginger
Dermestes frischii	turmeric
Dermestes lardarius	nutmeg
Dienerella ruficollis	chili pepper
Dinoderus minutus	cinnamon, ginger
Doloessa viridis	nutmeg
Ephestia elutella	chili pepper, garlic, nutmeg
Ephestia kuehniella	chili pepper, garlic
Euscelinus sarawacus	nutmeg
Gibbium psylloides	chili pepper, coriander, ginger, spearmint, turmeric
Gnatocerus cornutus	ginger
Gnatocerus maxillosus	nutmeg
Himatismus villosus	chili pepper
Holoparamecus depressus	black pepper, ginger
Holoparamecus signatus	ginger
Hypothenemus obscurus	nutmeg
Lachesilla pedicularia	coriander
Lasioderma serricorne	allspice, anise, basil leaf, black pepper, cardamom, chili pepper, cinnamon, coriander, cumin, curry powder, garlic, ginger, ginseng root, nutmeg, onion, paprika, saffron, spearmint, turmeric
Latheticus oryzae	chili pepper
Liposcelis bostrychophila	black pepper, ginger
Liposcelis decolor	black pepper
Liposcelis entomophilus	black pepper
Lonchaea polita	black pepper
Lophocateres pusillus	chili pepper, ginger, nutmeg
Lyctus africanus	ginger
Lyctus brunneus	cinnamon

Table 1. *Insect species associated with spices and other seasonings (modified from Hagstrum and Subramanyam 2009).*

Insect	Spice/Herb
Mezium americanum	chili pepper
Monanus concinnulus	chili pepper
Murmidius ovalis	ginger
Murmidius segregatus	ginger
Nausibius clavicornis	ginger
Necrobia rufipes	chili pepper, garlic, ginger, nutmeg
Opatrum subaratum	ginger
Orphinus fulpinus	ginger, nutmeg
Oryzaephilus mercator	anise, black pepper, chili pepper, coriander, curry powder, ginger, ginseng root, nutmeg, turmeric
Oryzaephilus surinamensis	black pepper, coriander, curry powder, nutmeg, paprika
Palorinus humeralis	nutmeg
Palorus cerylonoides	nutmeg
Palorus genalis	ginger, nutmeg
Palorus subdepressus	ginger
Paralipsa gularis	pepper
Pharaxonotha kirschii	chili pepper
Phradonoma villosulum	chili pepper
Phthorimaea operculella	chili pepper
Plodia interpunctella	anise, chili pepper, garlic, ginger, nutmeg, onion, paprika
Ptinus fur	ginger, paprika
Ptinus ocellus	chili pepper, ginger, nutmeg, paprika
Pyralis farinalis	turmeric
Pyralis manihotalis	chili pepper, ginger
Rhyzopertha dominica	chili pepper, cinnamon, coriander, cumin, ginger, turmeric
Setomorpha rutella	black pepper, ginger
Sitophagus hololeptoides	nutmeg
Sitophilus oryzae	anise, black pepper, coriander
Sitotroga cerealella	black pepper
Sphaericus gibboides	chili pepper, coriander, curry, paprika, saffron
Stegobium paniceum	allspice, anise, black pepper, chili pepper, coriander, cumin, curry powder, ginseng root, onion, paprika, saffron, turmeric
Systole albipennis	anise, coriander
Systole geniculata	anise, coriander
Tenebroides mauritanicus	chili pepper, cinnamon, ginger, nutmeg, onion
Thaneroclerus buqueti	anise, ginger, nutmeg
Tinea pellionella	chili pepper, ginger, saffron
Tribolium anaphe	ginger
Tribolium castaneum	black pepper, cardamom, chili pepper, cinnamon, coriander, ginger, nutmeg, onion, oregano, turmeric
Tribolium confusum	black pepper, cardamom, chili pepper, coriander, ginger
Tricorynus herbarium	nutmeg
Tricorynus tabaci	chili pepper, garlic
Trigonogenius globosus	chili pepper
Trogoderma granarium	chili pepper, nutmeg, turmeric
Trogoderma inclusum	black pepper, garlic
Trogoderma ornatum	garlic
Trogoderma simplex	black pepper
Trogoderma sternale	chili pepper
Trogoderma variabile	black pepper, chili pepper, cumin
Trogoderma versicolor	chili pepper
Typhaea stercorea	black pepper, chili pepper, garlic, onion

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