MANAGEMENT OF MOTH PESTS INFESTING PROCESSED CEREALS: BIOLOGICAL CONSIDERATIONS

(2nd *Revision*)

D. Silhacek* and C. Murphy
USDA, ARS, CMAVE, Post Harvest Group, Gainesville, FL

***Introduction*:** Using alternatives to conventional pesticides to manage moth populations infesting processed commodities stored in clean warehouses required that we identify and investigate various parameters that comprise a successful infestation. Our objective was to use this information to develop new or improve existing methods for managing insect pest populations that would eliminate or minimize insect damage to processed commodities without invoking the hazards associated with conventional pesticide use. We report here observations on the mechanics of flour moth infestation of processed commodities during warehouse storage. Three infestation parameters were identified and studied: 1) Attraction of female moths to the commodity for oviposition; 2) Deposition of viable eggs by female moths on or near the commodity; 3) Nutritional quality of commodity for supporting the growth and development of moths. We have examined each of these three infestation parameters using the Indianmeal moth, *Plodia interpunctella,* and, in some experiments, the Almond moth, *Ephestia cautella* and the Mediterranean flour moth, *Anagasta kuehniella*, as well. Reported here is the progress we have made in understanding the mechanics used by the moth during its infestation of a commodity. The progress we have made in each of these areas is summarized below:

Attraction to commodity: We have developed methodology that gives a quantitative measure of a commodity's attractiveness to female moths. In warehouse tests, the three species of female test moths were attracted to more than one commodity for oviposition. However, the commodity most attractive to a particular moth species was clearly species-specific.

The behavior of flour moths during attraction to commodities stored in the warehouse was studied. We observed that moths began to emerge shortly before the onset of darkness, continuing to emerge through the scotophase. The newly-emerged moths usually drop to the floor and ambulate to the nearest vertical surface where they rest for several hours. Mating occurs largely on the walls, when wing-fluttering males bump into receptive females. Female moths are more active during the scotophase, when increased numbers are attracted to the commodity.

Oviposition and Embryonic Development: In the warehouse, female moths move to the commodity to lay eggs. Even though some eggs are laid directly on the commodity, many of them are laid in the vicinity surrounding the commodity or are laid on the outer vertical surfaces of the commodity container. We conjecture that some commodities have secondary molecules that promote oviposition directly on the commodity. In a clean environment, newly-hatched larvae cannot successfully infest a commodity if they have to crawl more than a few centimeters. Therefore, the larvae most likely to infest are those hatching from eggs laid directly on the commodity and from those laid on the commodity container.

The success of a moth infestation relies upon the normal development of the embryo. This developmental stage is particularly susceptible to alterations in environmental conditions during commodity storage. Moth fertility and embryogenesis can be affected in a number of ways. We have shown that embryogenesis in the three species of flour moths is disrupted by low levels of juvenoid agonists. These levels of agonists can be delivered to the developing embryo by contact of the egg or by contact of the gravid female with a treated surface. Juvenoid agonist applications can protect packaged commodities for a year during storage in warehouses.

We are also investigating the effects of temperature on egg laying and embryogenesis. The focus of this study has been to determine why elevating the 26°C rearing temperature of *A. kuehniella* to 30°C during the pupal stage abolishes subsequent reproduction. The mechanism of this effect on reproduction is still unclear, but could provide a new target when designing new control strategies.

Nutritional Quality of Commodity: In our warehouse tests, the nutritional quality of the commodity played a major role in determining whether or not flour moths grew and developed on the commodity. We found that processed cereal products currently in the marketplace can range between being fully supportive of flour moth growth and development to being totally non-supportive. Some processed commodities can attract moths for oviposition, but fail to support the growth and development of the newly hatched larvae. Nutritional inadequacy is only one factor that contributes to impaired growth and increased mortality. Other commodity determinants are hardness of the processed product, its palatability, its water content, and its texture. Identifying and defining these factors that are essential for moth growth may lead to the formulation of insect resistant food products that would not require pesticide intervention for protection.

We have made significant strides in simplifying the composition of the flour moth diet so that we can better identify the moths nutritional requirements for growth.

There was no infestation of packaged commodities for six months when heavy populations of Indianmeal moths were periodically released in a warehouse, where the walls and commodity boxes are treated with the agonist, fenoxycarb. Pyriproxyfen appears to be almost as effective as fenoxycarb (tests still in progress), but is less hazardous and has the advantage of currently being registered for use on some food crops in the field. We feel that these relatively safe JH_{Ag} have a real potential for protecting stored commodities from moth damage. Our protocol uses low levels of the JH_{Ag} and isolates it from the commodity for even greater safety. The most significant advantage of these JH_{Ag} applications are that they work before any commodity damage can occur.

Work in Progress and Future Plans

Ovipositional Failure

We are currently looking at pyriproxyfen as an alternative to fenoxycarb and may take a look at other juvenoid agonists, for example hydroprene and methoprene which already have some stored product applications. Other methods of application need to be examined. Finally, we need to make a push to get this methodology registered for protection of packaged commodities.

Attraction to Commodity

We have selected the commodity we feel is best suited for isolating the attractive principal. We have developed a bioassay that demonstrates specificity in attracting moths for oviposition. So our next step is to isolate and identify the chemical(s) that attract the flour moths to the commodities. As a corollary to this work we will also be looking for possible arrestants and ovipositional stimulants.

Nutritional Quality

It is evident that nutritional quality has a profound effect on commodity infestation. Some nutritionally acceptable products in the marketplace are already resistant to insect infestation because of nutrient inadequacy. First, we will identify the insect's nutritional requirements and ascertain why insects fail to grow on these products. Then we can engineer or process other food products that are nutritionally acceptable to man and make them nutritionally inadequate for insect pests.