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Rapid Determination of the Effectiveness of Insect Resistant Packaging

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Abstract—A technique was developed to evaluate the usefulness of odour barriers and to determine the effect of package content in consumer size packages on resistance to infestation by insects. Female *Plodia interpunctella* (Hübner) could distinguish sealed packets containing food from non-food items as a suitable site for oviposition. Utilization of this technique will reduce the time needed to evaluate new materials for use in insect resistant packaging.

Key words—Indianmeal moth, *Plodia interpunctella*, insect infestation, attractancy, odour barrier.

INTRODUCTION

Studies of insect control in packaged foods must include investigations of packaging and materials used in modern food storage and distribution systems. Most non-perishable foods are shipped in consumer-sized packages and, with the exception of canned food, most are subject to attack by insects. Insect infestation is a major cause of loss in packaged foods. These losses generally occur because insects either bore through package material (penetrators) or enter the package through existing holes either caused by imperfect seals or overwraps, mechanical damage, or damage resulting from previous insect infestation (invaders) (Highland, 1984). Newly hatched insect larvae can make their own holes or enter through existing openings in the packages. Cline and Highland (1981) found that adult red flour beetles, *Tribolium castaneum* (Herbst), can enter through openings less than 1.35 mm in diameter. Newly hatched insect larvae can be expected to enter through much smaller holes. Yerington (1978) showed a direct correlation between package seals and the extent and swiftness of the infestation. Mullen and Highland (1988) found that packages of non-fat dry milk were more susceptible to insect infestation if major defects were present.

Determining the resistance to infestation of packaged foods by insects generally take 3–6 months. Tests are usually designed so that packaged foods are exposed to a variety of insects for a period of time with destructive breakdowns occurring each month until all package types fail. One indicator of potential infestation is the attractiveness of the particular food to the pest insects.

In a related study using the almond moth, *Ephestia cautella* (Walker), Barrer and Jay (1980) found that free flying gravid females tended to oviposit near the source of a grain odour. As an initial step in developing this method I decided to exploit this behaviour using Indianmeal moths, *Plodia interpunctella* (Hübner), to determine if free flying females would deposit eggs at a site that would provide a suitable food source for the developing larvae. A faster method to determine infestation barrier potential of food packages would result in a significant reduction in the costs of developing resistant packages. In this report a rapid method is described that tests the effectiveness of odour barrier packaging materials to determine the infestation potential of food packages, as well as to determine the infestability of particular food products.

MATERIALS AND METHODS

Preliminary tests (Test 1) were conducted using 7.6 × 12.7 cm packages made from polyethylene coated kraft paper. Three sets of packages containing about 40.0 g each of oat or wheat flaked breakfast cereal were used. One of the cereal types contained a mixture of dry fruits and nuts. The remaining cereals were basic flakes with no fruits or nuts. A fourth set of packages contained only paper towels. All packages were heat sealed and placed singularly in black construction-paper trays made by folding the edges of an 21.6 × 27.9 cm sheet up to form sides approx. 1.3 cm in height. Cellophane tape was used to hold the sides together. Ten packages each were randomly placed into a room (5.4 × 2.4 × 2.4 m). One open culture of emerging *P. interpunctella* (approx. 500 ♂ and 500 ♀) was suspended in the center of the room approx. 1.8 m from the floor. The emerging adults had free access to the room to mate and oviposit for 72 h. The packages were then carefully removed from the trays and moth eggs were brushed off the packages into the trays. Only the eggs oviposited on the packages and in the trays were counted. Each test was replicated 3 times.

In Test 2, dry dog food with either a tallow or animal fat coating was compared to dry dog food and puppy food without the coatings to determine *P. interpunctella* oviposition preference. Packages were constructed as in the previous test and about 60 g of dog food was placed in each package. Control packets were filled with paper towels. Ten packages of each food type were used and the test was not replicated.

Test 3 compared commercially prepared packages of breakfast cereal containing raisins and nuts packaged in flexible liners made of different materials. The outer boxes were removed so that only the liners were tested. Two of the liners incorporated odour barriers while the third was the normal liner now used commercially. Larger egg collection trays were made from two sheets of construction paper taped together because each cereal bag contained 567 g of product. Two replications of ten bags of each type were exposed to approx. 1000 adult *P. interpunctella* for 72 h. No paper towel control packets were used in this test.

Egg counts were compared using the ANOVA procedure with Duncan's multiple range test (SAS Institute, 1987). The products used in these experiments are not specifically named because they are covered by confidentiality agreements under established Cooperative Research and Development Agreements with the manufacturers.

RESULTS AND DISCUSSION

Results of Test 1 showed that female *P. interpunctella* were able to distinguish cereal products containing the fruit and nut mixture (24.1 $\pm$ 5.6 eggs) from those containing only cereal flakes (5.0 $\pm$ 2.1 and 4.4 $\pm$ 0.9 eggs respectively) as well as the paper towel control (1.2 $\pm$ 0.4 eggs) ($F = 11.64$; $df = 3$; $P \leqslant 0.0001$).

Similar results were found in Test 2. In this case dry dog food with chicken fat (306.0 $\pm$ 17.2 eggs) or tallow (239.4 $\pm$ 33.4 eggs) were less attractive than either the store purchased dog food (431.2 $\pm$ 35.5 eggs) or the puppy food (362.3 $\pm$ 21.1 eggs). All were more attractive than the paper towel controls (30.7 $\pm$ 7.6 eggs) ($F = 39.99$; $df = 4$; $P \leqslant 0.0001$).

Test 3 showed that packages containing odour barriers were less attractive to female *P. interpunctella* than packages not having these liners. Both odour barrier liners had significantly fewer eggs (31.7 $\pm$ 6.1 and 42.5 $\pm$ 8.4 eggs respectively) than the control (153.5 $\pm$ 26.8 eggs) ($F = 16.45$; $df = 2$; $P \leqslant 0.0001$).

Insect resistant packaging has been shown to be an important way to reduce dependance on insecticide treatments. Although it may be more economical to make the outer shipping container insect resistant, it may be more desirable to make the consumer-sized package insect proof. The development of a technique to evaluate odour barriers as a means of developing an insect resistant package will allow us to rapidly evaluate new packaging material and techniques as well as testing overwraps and seals. In addition, the importance of packaging defects can be evaluated as they relate to insect resistance. Mullen and Highland (1988) found that minor defects in fiberboard packages of dried milk overwrapped with a paper/polyethylene/foil moisture-proof laminate sealed with a wax-like coating had little effect on insect infestation. This test was conducted over a period of 6 months. The availability of a technique such as the one described above could reduce the time to evaluate the packaging materials to less than 2 weeks.

Barrer and Jay (1980) showed that *E. cautella* can use odours to trigger oviposition. This new method shows that generally *P. interpunctella* females can discriminate between the contents of sealed packages to determine suitable oviposition sites. However, making a food container less attractive to insects is only part of total package protection. Tests to evaluate materials for resistance to penetration by insects have been described (Cline, 1978; Dal Monte, 1969; Davey and Amos, 1961; Domenichini and Forti, 1975). Inclusion of the method described in this study as well as tests for penetration and careful attention to good seals, closures, and overwraps in the development of a new package will maximize protection of foods from insects. This is of particular importance in the current environment of consumerism when the packager/producer is held responsible for the quality of the packaged foods they produce.

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