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Characterization and measurement of semiochemicals for management of stored product pests

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Abstract

This work describes research conducted as part of a cooperative agreement between ARS and Sensor Development Corporation (SDC). ARS and SDC have teamed to identify key natural products used by stored product insects for signaling, as well as chemical signals that are diagnostic of infestation. SDC specializes in the engineering and commercial application of gas sensor technologies, particularly the detection of volatile organic compounds in commercial as well as quarantine settings across the globe. SDC has developed a prototype detector capable of detecting several natural products produced by a suite of stored product pests. Recent research findings will be presented for proof-of-concept testing for detection of indianmeal moth and navel orangeworm in simplified laboratory-scale experiments.

Keywords: Semiochemical, Stored product pest, Indianmeal moth, Navel orangeworm

Introduction

Insect pests are a key contributor to the estimated postharvest food loss of 9-20% worldwide (Pimentel, 1991) and 20-40% in African countries (Kumar and Kalita, 2017). Current post-harvest technologies for detecting early stages of infestation are either cost-prohibitive or ineffective, at least for key pests such as indianmeal moth (IMM), *plodia interpunctella* (Hübner), and navel orangeworm (NOW), *Amyelois transitella* (Walker). Immunoassay-based approaches to monitoring stored products are effective but are destructive and require sample preparation, staff training, and analysis. A novel nanocrystalline tin-oxide sensor developed by Sensor Development Corporation (Elyria, OH) has shown promise in proof-of-concept testing at the laboratory-scale as a rapid, inexpensive, and easy-to-operate real-time (or near real-time) detector for a host of such early infestations. The aim of the work described herein is to demonstrate effective detection of IMM and NOW in simplified conditions and set a detection baseline for future testing and development endeavors.

Materials and methods

All life stages of IMM and NOW were sourced from the USDA-ARS-SJVASC insectary (Parlier, CA, USA). Flour was purchased at a local grocery store, and bins of almonds were provided by a local packing house. Headspace sampling and analysis were performed using a custom thin-film sensor unit produced by SDC (Sensor Development Corporation, Elyria, Ohio). Two 37.9 L galvanized steel pails with loose-fitting lids were modified with 3/8 in stainless steel tubing and stainless-steel Swagelok (Solon, OH) fittings. A Swagelok fitting was installed 12 cm from the top of each pail which connected to an 11 cm length of tubing connected to a ball valve. Both ball valves were connected to opposite arms of a tee union with a 3.5 cm length of stainless-steel tubing, thereby linking the pails. The prototype gas sensor was attached to a length of tubing that connected to the stem of the tee union. Each pail was loaded with 2.3 kg of store-bought all-purpose flour. One-pint Ball (Ball Corporation, Broomfield, CO) glass canning jars fitted with metal mesh lids were loaded with a single life stage of either IMM or NOW: egg, larva, pupa or adult.

Galvanized pail testing

The galvanized pails were used to assess the relative sensitivity of the SDC sensor to various numbers of each IMM life stage. One metal galvanized pail was loaded with a glass jar containing one life stage of IMM and the other contained only the store-bought flour. The headspace of the flour-only pail was sampled until the sensor had established a steady baseline and then the flow for the flour pail was toggled off and the pail with the IMM jar was toggled on. The pail with the IMM in it was sampled for 15 min and then the gas flow was toggled back to sampling the flour-only pail while the IMM jar was changed out.

The SDC sensor was also tested with all life stages of NOW in amounts of 50 pupae, larvae, or adults; 100 eggs, pupae, larvae, or adults; and 200 eggs. Test conditions were the same as those previously described for the IMM galvanized pail testing.

Blind testing

A set of single-blind-type tests were performed with the sensor in which a glass jar containing 5, 25, 100, 150, or 225 IMM pupae were placed in the test pail without the sensor operator knowing the contents of the pail. The sensor operator then used the data collected in the previously described galvanized pail testing to estimate the number of pupae present for each group. The accuracy of the sensor for each group of IMM pupae was calculated by the formula

$$Accuracy = \left(1 - \frac{|A - C|}{A}\right) * 100\%$$

Where; A is the actual count of pupae and C is the calculated number of pupae from the linear regression model. Pupae were used for the test because they elicited the strongest response per insect, and each jar was tested a single time in the blind testing.

Results and discussion

The SDC sensor was able to detect all life stages of IMM. However, the detection response varied for each life stage. IMM pupae gave the highest detection response (Fig. 1), and the response from IMM eggs, larvae and adults was lower. The data collected so far indicate that the sensor could be used to detect IMM before they develop to adults and have the opportunity to lay eggs. This would pre-empt trapping and visual detection of adults for cases in which eggs are brought into a storage situation or the first-generation adults are undetected. In this early sensor development stage, there were some possible concerns with baseline drift as seen in the flour only sections of Fig. 1.

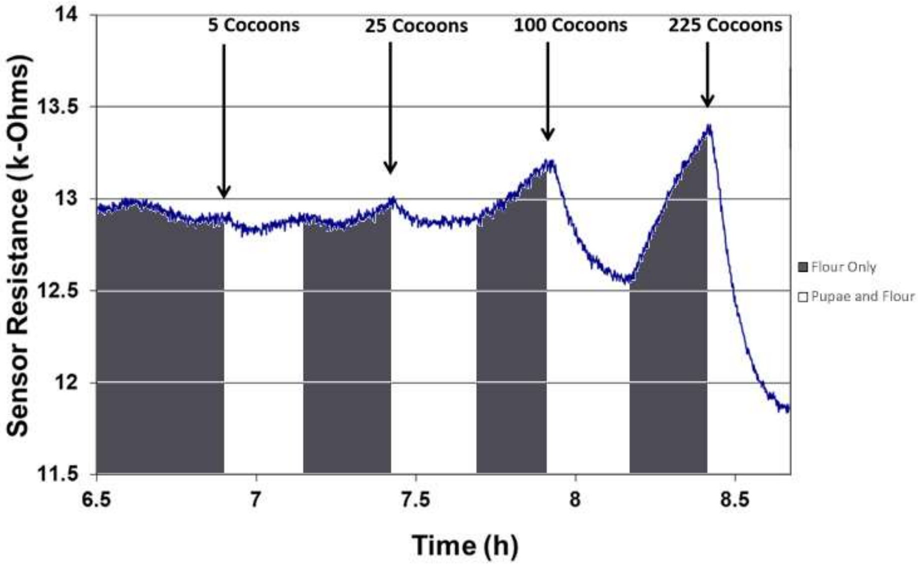

Fig. 1. Flour pail test results with cocooned IMM pupae. Sampling alternated between the flour only pail and the IMM/flour pail as indicated by the shading below the sensor readout.

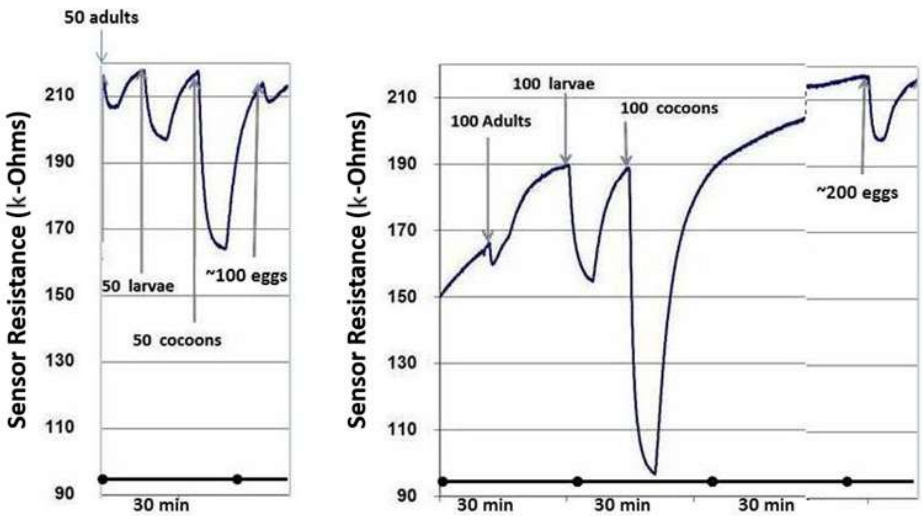

Fig. 2. Sensor readout data from navel orangeworm life stage detection. Although all life stages were detected, cocooned pupae elicited the strongest response.

The SDC sensor was able to detect all life stages of NOW, and the sensor had greater sensitivity for NOW than IMM (Fig. 2). Cocooned pupae elicit the strongest response, followed by larvae, adults, and eggs, in decreasing order of response strength.

Sensor response (net conductivity) data from the IMM pail testing was fitted with a linear least-squares regression model and used to estimate the number of specimens in a series of single-blind tests. Estimations based on the regression model were 76-92% accurate over a range of values from 5 to 225 IMM pupae (Table 1). The linear response of the sensors shows promise for determining the presence of pests as well as the severity of the infestation, thereby guiding disinfestation and IPM strategies.

Table 1. Single-blind testing results for SDC sensor with IMM pupae; each quantity of pupae was tested once

Actual Pupae	Calculated Pupae	Accuracy
5	4	80%
25	23	92%
100	124	76%
150	135	90%
225	253	88%

If proven as a robust and accurate pest detector, the novel nanocrystalline tin oxide sensor developed by SDC presents a viable electronic monitoring option that would be price-accessible, simple to use, and easy to maintain for quality control and storehouse monitoring of IMM, NOW, and other stored product pests. So far, the SDC sensor has demonstrated the ability to detect IMM and NOW in simple proof of concept testing, and the range of detection is encouraging for possible use as an early detector of pest infestation. The SDC sensor, which is non-intrusive toward commodities, has thus shown promise for use in QC sampling.

Future studies will explore the sensor's ability to differentiate between pest species, but in most expected applications any pest presence is problematic and provides valuable information for the user. Improving baseline stability will also be a focus of future investigation. Characterization and optimization of the sensor using insect semiochemicals via gas chromatography mass spectrometry is planned and will be conducted once a beta test unit is available.

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