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Review

Aspects related to decision support tools and Integrated Pest Management in food chains

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ABSTRACT

There are a number of tools available for pest management in stored product protection and in the food industry, but often the effectiveness of these approaches and how best to integrate them into a coherent and effective Integrated Pest Management (IPM) programme are not well understood. Many questions remain about the use of these tools, from the very practical issues such as how many traps are needed and which types work best, to fundamental issues concerning the relationship between trap captures and pest population density, distribution and level of product infestation. Limited acceptance of IPM in food facilities is partially explained by a combination of: costs of responsive pest control interventions; difficulty in sampling properly, combined with unreliable sampling data; calculations of action thresholds being too simplistic. In operational practice precise treatment thresholds and economic injury levels have not been developed, and standards and rejection criteria are inconsistent and difficult to apply. As a result, treatments based on an economic threshold are not typically performed and control strategies are often applied preventively, even when using tactics that do not have any residual effect. In current practice, many locations still rely on calendar-based pesticide applications and have little understanding of the basis of pest management.

Contents

1. Introduction

In recent decades, the food industry has been moving away from structural fumigations and calendar-based chemical pesticide applications towards Integrated Pest Management (IPM). This shift has been driven by the loss of pesticides such as methyl bromide, consumer demand for reduced pesticide usage, and development of 'precision-application' technologies and pest guidelines. At the same time, pest management and food safety practices must protect food products as many markets have very low pest-induced damage tolerance and are also subject to increasingly intense scrutiny through external inspections and audits. These somewhat antagonistic trends (less reliance on and use of pesticides, and the demand for perfect food products) highlight one of the main challenges faced by the food industry.

Food facilities typically are large, complex structures with many locations vulnerable to insect infestation. They differ from each other in function (warehouse, mill, food processing), commodity (cereals, animal-based materials, spices), product generated (flour, whole grain, human food or pet food), structure type (old or new, construction material), equipment, geographic location and surrounding landscape, as well as other factors. This makes generalizations about pest management difficult. Facility conditions can

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change over time due to seasonal fluctuations, changes in physical structure and management, and other variables.

The pest situation must be characterised for a given place, and an IPM programme should be both tailored to a specific location and flexible enough to deal with changing conditions. A rigid or standard approach to pest management is rarely successful. Although pest management is part of a food facility's prerequisite programme, in many cases it can be implemented more effectively. Insect monitoring is an important component of pest management. Economic losses due to insects and unnecessary pest management expenses can be avoided using insect monitoring and decision-making tools such as economic thresholds, predictive models and expert systems to determine the best time to suppress pest populations.

Early detection of pest infestation is an essential component of successful pest management programmes. In general, effective monitoring requires a combination of trap and lure strategies, but because individual traps are only point sources of information there is great interest in methods that can predict the extent of a pest infestation throughout a storage facility. Such predictions depend upon both mathematical methodologies for interpolation and an understanding of pest distribution and behaviour. Computer simulation models can be used to compare the effectiveness of different pest management methods, alone or in combination, for stored-product insects. These models can also be used to evaluate the effectiveness of different implementation options, and to optimise the timing of pest management programmes for stored-product insects. Currently, computer simulation models are available primarily for insect pests of stored grain, but in the future such models will be useful in making pest management decisions throughout the marketing system.

The main objectives of this paper are to analyse aspects related to decision support tools in stored-product protection and their integrated application in practice.

2. Traps and trapping procedure

Insect monitoring can involve direct sampling of the commodity itself using visual inspection or traps to determine if the patch is infested, or indirect sampling of the insects dispersing among resource patches using tools such as pheromone traps. Direct product sampling is often destructive (e.g. packaged commodities) and can be difficult or prohibitively expensive (e.g. disassembling equipment, wall voids). Indirect sampling, although often easier to perform, yields information that is more difficult to interpret and use for making pest management decisions. This is because it is primarily dispersing individuals that are sampled, and often the methods used for their capture are biased towards a particular sex and/or physiological state. In most situations, the relationships between direct and indirect sampling methods are unknown (Campbell, Perez-Mendoza, & Weier, 2012; Hagstrum, 2000), and few studies have addressed this important issue (e.g. Hawkin, Stanbridge, & Fields 2013; Nansen, Campbell, Phillips, & Mullen, 2003; Nansen, Phillips, Parajulee, & Franqui-Rivera, 2004; Nansen, Phillips, & Sanders, 2004).

Monitoring strategies and tactics differ between bulk-stored raw commodities and processed commodity facilities. Bulk-stored commodity monitoring relies primarily on direct sampling for insects in the product, but for processed commodity facilities a combination of direct and indirect sampling is more widely used. The major difficulty with bulk grain sampling is that extrapolation of sample data to estimate the number of insects present in a very large volume can be inaccurate due to various factors, including the small volume of samples relative to the total volume of stored grain, the low density and non-uniform distribution of insects, and the difficulty in taking samples from throughout the grain mass. Prediction of infestation level using sticky traps in bean headspace and in stored peanuts has been reported by Hagstrum, Dowdy, and Lippert (1994) and Nansen, Davidson, and Porter (2009).

Various tools (e.g. grain trier, pelican sampler, vacuum probe) are available for collecting grain samples, and their use is determined by the volume of grain to sample and whether it is in a bin or being moved. These samples are then sieved, either with a hand-held or an inclined device to remove external insects from the grain (Subramanyam & Hagstrum, 1995). However, many of the important bulk grain pests are internal feeders and are difficult to detect (Trematerra & Throne, 2012). A number of methods have been developed to detect insects hidden inside grain kernels, including (i) staining kernels to detect weevil egg plugs, (ii) density separation based on infested kernels being lighter weight and floating in a liquid, (iii) detection of carbon dioxide or uric acid produced by the internally feeding insects, (iv) detection by nuclear magnetic resonance, (v) detection by standard film or digital X-ray images that may be combined with automated image analysis, (vi) acoustical sensors that detect insects feeding inside kernels, and (vii) enzyme-linked immunosorbent assays that detect myosin in the muscles of insects (Throne & Pearson, 2008).

Some of the recently developed methods to detect insects hidden inside kernels include near-infrared spectroscopy, adaptation of the single-kernel characterization system, computed tomography, acoustic impact emissions (dropping kernels and recording the sounds made when they hit a steel plate), and use of a conductive mill (determining conductivity of a kernel as it's milled). Problems encountered with these approaches are that the most accurate methods (e.g. X-ray) are laborious and expensive, whereas rapid, automated methods tend to not be able to detect eggs and young larvae (Throne & Pearson, 2008). Fleurat-Lessard, Tomasini, Kostine, and Fuzeau (2006) reported two different versions of a computer-assisted acoustic system (EWD P3™ and EWD LAB™) for monitoring insect density in grain bulks that do not need sample collecting. A portable probe acoustic detection system calibrated for *Sitophilus oryzae* and *Rhyzopertha dominica* exists, and this new tool is associated with decision support systems for IPM implementation in grain handling and storage plants. The potential for the RAPD-PCR technique to provide useful genetic data for discrimination up to the inter- and intra-specific level of insects found in stored products in international trade was also reported by Fleurat-Lessard & Pronier (2006). The comparison of acoustic probe and manual assessment of insect population density in practical situations of grain storage sites of western France was reported by Leblanc, Gaunt, and Fleurat-Lessard (2011). The light filth method (i.e. filth test) can also be used for monitoring insect fragments and rodent hairs present in food (FDA, 1988; Trematerra, Stejskal, & Huber, 2011).

An indirect approach commonly used by industry to assess insect density is to determine the number of insect-damaged kernels (IDK) present in samples. Unfortunately, IDK and internally feeding insect numbers are not always related (Perez-Mendoza, Flinn, Campbell, Hagstrum, & Throne, 2004).

Monitoring of insects in warehouse and food processing structures involves either direct visual sampling or the use of traps. Visual inspection done on a regular basis is one of the primary means by which insect infestation is monitored in food facilities. The strength of this approach is that not only does it detect signs of insect infestation, but it can also identify potential problem areas such as accumulations of spillage before they become infested. However, in many cases food patches are not detectable or access requires destructive sampling that makes detection difficult until