BIOSENSING APPROACH FOR QUANTIFYING FUMIGATION EFFICACY & REDUCED MeBr USE

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For decades structural fumigation has remained more of an art rather than a science and it has been performed without any type of direct efficacy measures. Applicators typically overdose in order to ensure the success of fumigation event. Methyl bromide (MeBr) has been the preferred fumigant in the structural pest control industry due it fast reaction and high efficacy. In addition, the per pound cost of MeBr has been relatively low because it is a by-product of other bromide manufacturing processes. Therefore, overdosing has been regarded as an assurance measure for fumigation success rather than misuse, and the importance of fumigation planning and monitoring has been largely overlooked.

Over the years, the fundamental aspects of structural fumigation processes have changed little. The main steps are (1) the structure is sealed in order to make it as gas-tight as possible, (2) the fumigant is released and held in the structure for a certain period of time, called exposure time, and (3) when the desired exposure has elapsed, the structure is aerated. Precision fumigation requires preparation of a fumigation management plan, and consideration of worker health and safety, food safety, insect resistance and environmental concerns.

For current fumigation practice, a fumigation event is considered successful when the lethal Ct product dosage has been reached. Lethal Ct product for different types and life stages of insect pests vary and are a function of temperature. Typically, eggs are the most tolerant stage while adults are more susceptible. Therefore, the Ct product is a function of fumigant concentration, exposure time and insect mortality that is typically quantified based on fumigation experiments under laboratory conditions in which the fumigant concentration and fumigated space temperature are maintained constant. No mathematical/statistical model can ever perfectly describe all characteristics of a biological system. Therefore, when used in a practical situation, the Ct product carries a certain level of uncertainty with it and thus it is not a definite mortality indicator. Currently, insect bioassays are considered ultimate proof of insect mortality, but they cannot be examined until the fumigation is completed. In the case of eggs, no simple method exists to determine vital signs.

During the phase out process of MeBr, it is important that MeBr emissions should be reduced due to its ozone-depleting capabilities. Simultaneously, as MeBr alternative gases are synthesized, their practical efficacies need to be compared to MeBr efficacy to facilitate MeBr transition. This creates the need of a technology which can impart insect mortality and fumigation efficacy information in real-time during the fumigation process.

Until now no tool exists that enables pest control professionals to directly measure fumigation efficacy while the structure is under gas. We propose to develop a real-time whole organism biosensor system based on the measurement of oxygen respiration, which is considered to be a hallmark indicator of life. Mitochondrial oxygen consumption is a key physiological signature of aerobically respiring organism. Recently, the mitochondria has re-emerged in importance in biological research as the evidence supports that they are integral in regulating key processes in cell biology, including molecular metabolism, calcium signaling and programmed cell death in addition to energy production.

We propose to use optical sensors (optrodes) instead of electrochemical microelectrodes to measure oxygen consumption. An optrode is the optical equivalent of an electrode that is constructed based on an analyte selective indicator molecule that changes its optical properties in response to analyte concentrations. Due to the advancement of the optical components miniaturized optical based whole-organism biosensors can be developed on the concepts of fluorescence quenching. Optrodes have significant advantages over their electrochemical counterparts (1) oxygen is not consumed by the sensor thereby eliminating sensor artifacts; (2) there is no reference electrode; (3) they are immune from external electromagnetic interference; and (4) have higher sensitivity and hence can be used to measure oxygen consumption of insect eggs.

In Physiological Sensing Facility at Purdue, we have demonstrated that optrodes can measure dynamic oxygen consumption by red flour beetle eggs under the influence of mitochondrial respiration inhibitors such as nitric oxide and potassium cyanide. Based on these experimental results, we believe that real-time whole organism biosensors can be miniaturized and developed for measuring insect mortality and quantification of fumigation efficacy. We envision that the real-time whole organism biosensor can be applied to

- Optimize and minimize MeBr use during phase-out and alternative gas use such as sulfuryl fluoride (SF) during phase-in by directly measuring biological efficacy.
- Standardize laboratory and field tests of new fumigants so they can be directly compared to MeBr.
- Facilitate high throughput screening and testing of alternative fumigant and residual pesticide molecules.