Efficacy of Heat to Disinfest Concrete Grain Silos

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Introduction

Alternative control measures for stored product pests are needed due to concerns of insecticide residues in food from grain protectants.

Fumigants leave no insecticide residues but there are concerns about transporting, handling, storing, and applying these products, and of insects developing resistance.

Heat is an attractive alternative because it eliminates some of the concerns. There are no insecticide residues, no transportation of products since heat is generated on-site, no storage issues of dangerous insecticides, and no long period of shutting down the facility.

Objective

Determine if heat is effective in controlling insect populations in concrete grain silos.

Fig. 1. Mobile Heat Treatment Unit

Fig. 2. Tube into bin

Fig. 3. Y-tube in bin

Protocol

Field experiments were conducted in 30.2 m tall empty concrete silos.

Three replications were completed, each on consecutive days, consisting of one heated silo and one silo under ambient conditions.

A Mobile Heat Treatment Unit was used to introduce heat into the bins (Figs. 1 - 3). When the average temperature in a heated silo reached 50°C, heating was continued only for the next 8 h.

Ventilated plastic containers with a capacity of 100 g of wheat kernels held all life stages of *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) (Fig. 4) and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) (Fig. 5).

Polyvinyl chloride containers with a capacity of 300 g of wheat held adults of two psocid species: *Liposcelis corrodens* (Heymons) (Psocoptera: Liposcelididae) (Fig. 6) and *L. decolor* (Pearman) (Fig. 7) which were contained in 35 mm Petri dishes within the grain.

Bioassay containers were fastened to a rope suspended from the top of the silo at depths of just under the top manhole, 10.1, 20.1, and 30.2 meters below the top manhole with each container fitted with a temperature recording device. (Fig. 8).

Adult mortality was determined after removing containers from the silos.

For beetles, after adult mortality was determined, grain was held at 28° C and 70% RH for four weeks to determine progeny production.

Fig. 4. *Rhyzopertha dominica*

Fig. 5. *Tribolium castaneum*

Fig. 6. *Liposcelis corrodens*

Fig. 7. *Liposcelis decolor*

Fig. 8. Bioassays in bin

Propane Usage

- Average of 288 liters of propane per silo
- Cost per liter was $0.79 on May 1, 2008
- Total cost per silo was $228.00
- Equivalent phosphine pellets to treat silo:
  - 4,000 – 18,000 pellets per silo
  - $34.30 – $155.05 based on a cost of $300 per case of 21 flasks of pellets

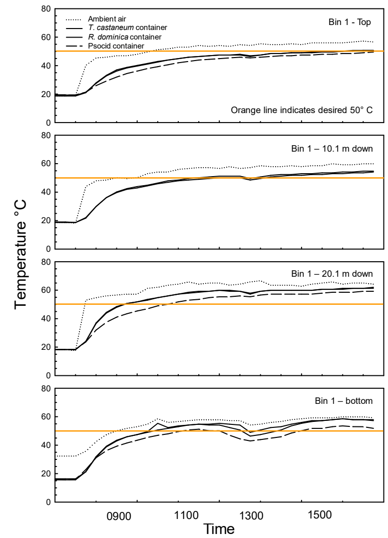

Fig. 15. Temperatures in a heated bin

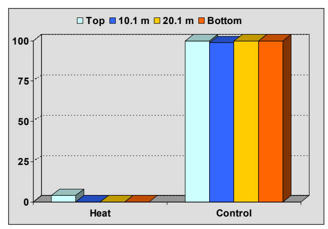

Fig. 9. Percent survival of *T. castaneum* adults

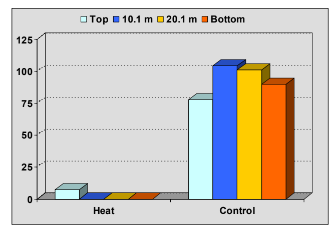

Fig. 10. Progeny production of *T. castaneum*

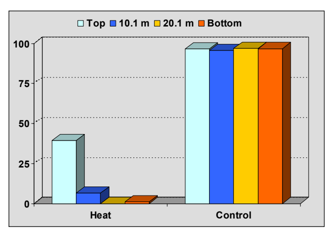

Fig. 11. Percent survival of *R. dominica* adults

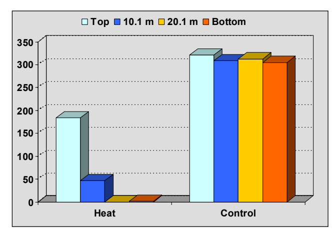

Fig. 12. Progeny production of *R. dominica*

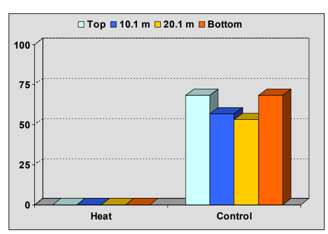

Fig. 13. Percent survival of *L. corrodens* adults

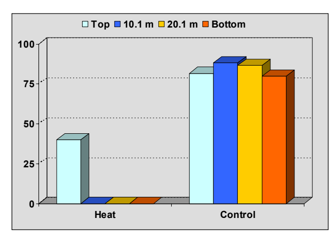

Fig. 14. Percent survival of *L. decolor* adults

Results and Conclusions

- There was 100% mortality of adult *T. castaneum* at the lower three depths but 4% survived at the top where it was slightly cooler, while >99% survived in the control bins (Fig. 9).
- *T. castaneum* progeny were produced only near the top in the heat treatments (Fig. 10).
- For *R. dominica*, adult survival in the heat treatments averaged 39.3, 6.6, 0, and 1.0% at increasing depths – corresponding to temperature data, while survival was greater than 95% in the control bins (Fig. 11).
- Progeny of *R. dominica* was produced at all depths in the heat treatments except where there was no adult survival (Fig. 12).
- *R. dominica* had greater heat tolerance compared to *T. castaneum*.
- There was 100% mortality of *L. corrodens* at all heights in the heat treatments (Fig. 13) but only 92.5% mortality for *L. decolor* with those surviving being located at the top (Fig. 14).
- *L. corrodens* appears more susceptible to heat than *L. decolor.*
- Only 100 g of wheat has a strong insulating effect (Fig. 15); therefore sanitation is critical when using heat.
- Cost of treatment using propane heaters is greater than using phosphine pellets.

Phosphine Resistance in Rusty Grain Beetles, *Crytopolestes ferrugineus* (Stephens), (Coleoptera: Laemophloidae) from Stored Wheat in Oklahoma

C. ferrugineus

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Introduction

Oklahoma produced 4.2 million tonnes (155 million bushels) of winter wheat (*Triticum aestivum* L.) worth $1.2 billion in 2012 (National Agricultural Statistics Service [NASS] 2013). Due to the comparatively warmer temperatures in Oklahoma, stored-product insect pests pose a significant risk to wheat in storage. The rusty grain beetle (RGB), *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Laemophloidae) is an important pest of stored wheat in Oklahoma. The larvae of this beetle often feed on the germ of whole kernels and fine material in the grain bins, while the adults feed mainly on damaged kernels or fine material as well. *C. ferrugineus* normally does not contribute to insect damaged kernels (IDK). Grain with high infestations of this insect usually receive lower market pricing compared to un-infested grain (Flinn et al. 2010). In Oklahoma PH_3 is the method of choice for fumigating stored grain to manage stored-grain insect pests. Stored wheat in commercial grain storage facilities in Oklahoma is fumigated using PH_3 on average 3 times each year (Cuperus et al. 1990). Governmental regulation of pesticides has significantly contributed to the common use of phosphine because it led to the loss of older fumigants, the declining use of methyl bromide, reduced use of residual contact insecticides because of harmful residues they leave in food, and the lack of alternative fumigants that are cost-effective, easy to apply, leave no residues, and can be used in a wide range of storage types and commodities like phosphine (Collins et al. 2001, Nayak et al. 2003, Phillips and Throne 2010). Heavy dependence on PH_3 in Oklahoma has led to the development of strong resistance in *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) (Opit et al. 2012). There are currently no published data on resistance to PH_3 in *C. ferrugineus* in USA. Therefore, we investigated PH_3 resistance in *C. ferrugineus* populations collected from Oklahoma, USA.

Objective

This study was designed to determine whether populations of *C. ferrugineus* from commercial grain storage facilities in Oklahoma are resistant to PH_3.

Materials and Methods

***Experimental insects*: *C. ferrugineus* was sampled from both farm storage bins and commercial elevators at 13 locations in the state of Oklahoma, USA. These insects were laboratory reared separately according to their locale at 28ºC and 65% RH .**

***Discriminating PH_3 Concentration*: A discriminating concentration of 56.15 ppm or 0.079 mg/L PH_3 was determined in a previous laboratory dose-response experiment where a susceptible laboratory strain of *C. ferrugineus* was exposed to concentrations ranging from 5.3 to 50 ppm for 20 hours. The dose-response test was conducted according to the FAO Method No. 16 (Food and Agriculture Organization 1975). The response of insects to PH_3 was subjected to probit analysis using PC-SAS version 2 (SAS Institute 2012). The discriminating concentration (56.15 ppm) was equal to the upper limit of the 95% confidence interval of the LC_{99} for the susceptible laboratory insects. The PH_3-susceptible laboratory strain of *C. ferrugineus,* maintained since 1972, was obtained from a laboratory culture at the Center for Grain and Animal Health Research (CGAHR) of the USDA Agricultural Research Service, Manhattan, KS.**

PH_3 Resistance Detection Bioassay

- **Fumigation jars consisted of 3.8-liter glass jars with lids modified to allow for a sampling port (Fig. 1). Altogether 6 fumigation jars containing insects were used. Three jars were assigned to the discriminating PH_3 concentration treatment and the other 3 to the control treatment (jars not dosed with PH_3) .**
- **A rubber septa was placed over the sampling port for introduction of PH_3 into jars and removal of gas samples for PH_3 quantification.**
- **For each of the 13 populations of field-collected *C. ferrugineus,* 50 insects were placed in each of six vials and a single vial was placed in each of the fumigation jars, i.e. a replication of 3.**
- **Another six vials containing 50 insects each from the susceptible laboratory strain were individually placed in each of six fumigation jars.**
- **Teflon® tape was used to facilitate sealing of fumigation jars containing *C. ferrugineus.***
- **The 56.15 ppm target concentration was attained by removing 30 ml of air from the fumigation jars then adding 22 ml of 10,000 ppm PH_3 .**
- **Fumigation lasted 20 hours and was conducted at 25°C and 70% RH.**
- **Presence of unaffected insects 2 weeks after fumigation, when mortality was assessed, indicated presence of PH_3 resistance.**

***PH_3 Quantification*:**

- **Laboratory fumigation methods and gas chromatographic-flame photometric detector (GC-FPD) quantification of average applied concentration of PH_3 in fumigation jars was by the use of methods described by Sekhon et al. (2010) (Figs. 2, 3, and 4). The Gas chromatograph used was a SRI instruments 8610 with a flame photometric detector (FPD) with an Rt™ – QS-Bond 30 meter, 0.53 mmID Silica Column (Fig. 2).**
- **The concentrations of PH_3 was measured at the start and end of the 20 -hour experiment run.**
- **The concentrations were established using a standard curve based on 50, 40, 30, 20, and 10 µl of 200 ppm PH_3 (Figs. 3 and 4).**
- **30 µl gas samples from fumigation jars were analyzed using the GC-FPD method described above in order to determine PH_3 concentrations in fumigation jars with PH_3.**

Fig. 1

Fig. 2

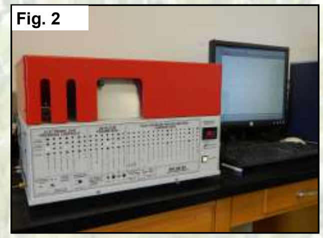


Fig. 3

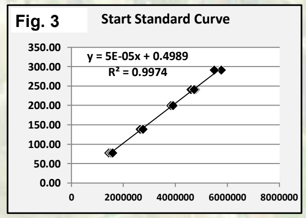
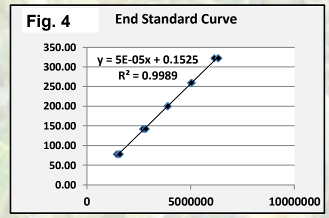


Fig. 4



Results and Discussion

- **Mortalities in control *C. ferrugineus* insects ranged from 0-8% but did not exceed 4% in 96% of the control data. Percentage survival data below are based on corrected mortalities (Table 1).**
- **All the 13 field-collected populations of *C. ferrugineus* had detectable PH_3 resistance. Resistance frequencies for the Johnston Enid and Douglas Kramer Farm 20 populations were extremely high (82-100%) (Table 1).**

Table 1. Survival (%) at 56.15 ppm for 20 hours of exposure

Population	Rep 1	Rep 2	Rep 3
Johnston Enid	100	92	82
Douglas Kramer Farm	44	32	31
Douglas Kramer Farm 20	100	94	84
Hennessy Bin 2	17	22	23
Hennessy Bin 3	10	16	24
Hennessy Bin 7	18	20	18
Hennessy Bin 11	31	28	38
Hennessy Bin 14	10	32	6
Kingfisher Bin 47	36	44	32
Kingfisher Bin 61	40	20	36
Kingfisher Bin 71	35	40	43
Kingfisher Bin 77	31	48	56
Kingfisher Bin 88	72	61	65
CGAHR (susceptible)	0	0	0

- **These data from only 13 populations of *C. ferrugenius*, from four Oklahoma counties, seem to suggest the existence of widespread PH_3 resistance in populations of this species in Oklahoma and probably the USA.**
- **The data also suggest that there may be strong resistance in some of the *C. ferrugenius* populations.**
- **Future research should comprise a survey of PH_3 resistance in *C. ferrugineus* from insects collected from throughout Oklahoma and other key grain growing parts of the USA.**
- **Additionally, dose-response tests to determine levels of resistance in field-collected populations of *C. ferrugenius* found to have high resistance frequencies needs to be conducted.**

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INTRA AND INTERSPECIFIC VARIATION ASSESSMENT IN PSOCOPTERA USING NEAR INFRARED SPECTROSCOPY

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INTRODUCTION

The near infrared spectroscopy (NIRS) is a type of vibrational spectroscopy which uses light energy at wavelengths from 750 to 2500 nm, and interaction between light and matter at such frequencies generates qualitative and quantitative information at the molecular level. Psocoptera is a neglected insect group, but contains many species associate with stored grains and deserve more taxonomic study, and NIRS can be a valuable tool in this regard. The objective of this study was to demonstrate that NIRS is a fast non-destructive and robust technique to discriminate sex and species of Psocoptera.

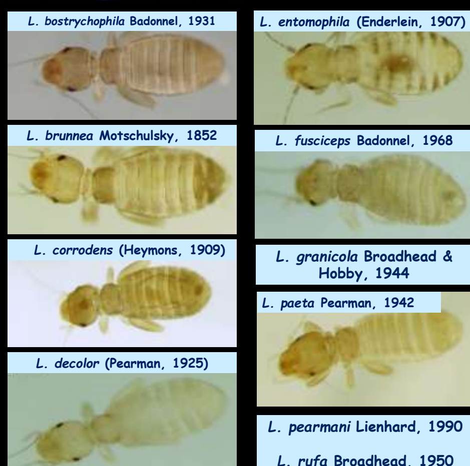
MATERIALS AND METHODS

Psocid species from laboratory cultures investigated by NIRS

LIPOSCELIDIDAE

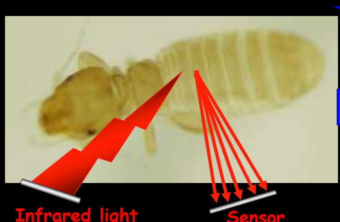
Advantages of NIRS:

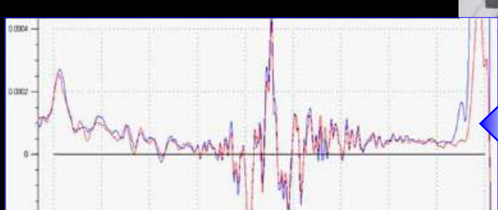
- universal application (any molecule with connections C-H, N-H, O-H and S-H);
- fast (1 min or less/sample);
- doesn't generate residues – solid, liquid or gaseous;
- clean technology;
- Small sample, in situ, or alive;
- no previous treatment of samples;
- non-invasive and non-destructive.



L. bostrychophila Badonnel, 1931; *L. brunnea* Motschulsky, 1852; *L. corrodens* (Heymons, 1909); *L. decolor* (Pearman, 1925); *L. entomophila* (Enderlein, 1907); *L. fusciceps* Badonnel, 1968; *L. granicola* Broadhead & Hobby, 1944; *L. paeta* Pearman, 1942; *L. pearmani* Lienhard, 1990; *L. rufa* Broadhead, 1950

Reflectance spectra (R) were obtained in a spectrometer Excalibur BIORAD, FTS 3500GX; equipped with KBr beam splitter; detector of deuterade triglicerin sulfate (DTGS); radiation source of silicon carbeto and accessory of diffuse reflectance in the NIR range (7500-400 cm^{-1}); resolution of 1 cm^{-1}; 64 scannings. Ten specimens of each species or sex were analyzed.





CONCLUSIONS

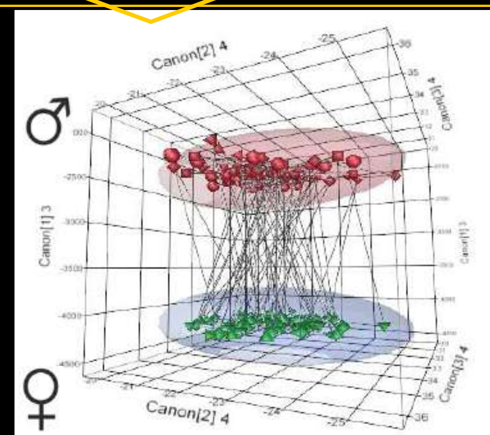
The NIRS technique is a promising alternative to distinguish Psocoptera sex and species, as shown in this study. The NIR spectroscopic character produced can be combined with morphological or molecular characters for taxon discrimination.

RESULTS

Discriminant analysis was used to test the NIRS generated data for sexual dimorphism, species discrimination and the combination of species and sex of psocids.

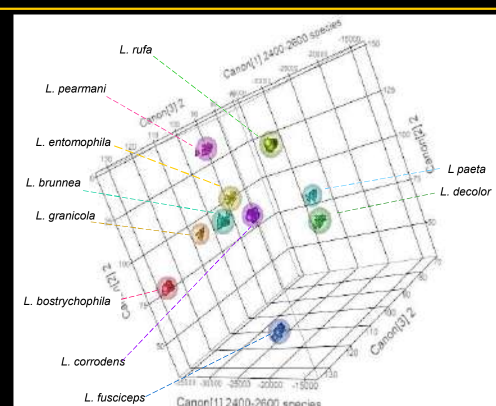
SEXUAL DIMORPHISM

The analysis separate both sexes independent of species with 100% resolution and a significantly high probability of each individual to belong to a given group in function of its sex, either male or female.
(Contour ellipses with 95% of probability)



SPECIES IDENTIFICATION

There was practically no overlapping of patterns between species when their NIR spectral data were analyzed by discriminant analysis.
(Contour ellipses with 95% of probability)



SEX AND SPECIES IDENTIFICATION

NIR spectral data can give sufficient information to discriminate simultaneously sex and species with 100% resolution.
(Contour ellipses with 95% of probability)