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IMPROVEMENT OF VACUUM EFFECT ON MORTALITY OF *SITOPHILUS GRANARIUS* (CURCULIONIDAE) USING OXYGEN CHEMICAL ABSORBER IN LABORATORY CONDITIONS

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ABSTRACT

The aim of this preliminary study was to find out if oxygen absorber can improve the efficacy of vacuum on mortality of stored product pests. The effect of vacuum (V) and vacuum in combination with the chemical absorber ATCO 400 (VA) on mortality of *S. granarius* adults was compared in dependence on temperature (15ºC, 25ºC), exposition time (1-7 days) and vacuum value (1.5 kPa). The airtight bags from aluminium and polyethylene films (size 10x25 cm) were used for laboratory experiments. Each bag contained a plastic 10 ml vial with 50 beetles (age 1-2 weeks) without grain substrate. The vials were closed with permeable caps. Seven replicates were used for each treatment. Bags were sealed using vacuum packing machine (KOMET Vacuboy). The results showed significant differences in efficacy of both V and V+A in dependence on temperature. Lethal time was 74 (LT_{50}) and 160 h (LT_{99}) of exposure in vacuum at 25ºC. Low temperature (15ºC) significantly prolonged the exposition time necessary for mortality of tested beetles in constant value of low pressure; LT_{50} and LT_{99} were 113 and 275 h, respectively. Suppression of exposition times was achieved with combination of vacuum and oxygen absorber (V+A); LT_{50} and LT_{99} were about 25h and 18h shorter at 25ºC and about 23h and 74h shorter at 15ºC in comparison with V treatment. Further research on comparison of V and VA effect is in progress including developmental stages in grain samples.

Key words: *Sitophilus granarius*, vacuum, oxygen absorber, MA storage, grain

INTRODUCTION

Relevant attention has been focused on bio-rational approach to managing stored-product insects in agricultural and food commodities to avoid use of chemical insecticides with their negative impact (Phillips and Throne, 2010). A non-chemical possibility is the utilisation of controlled and modified atmospheres (CA, MA) through the manipulation of physical environment (Longstaff, 1994; Stejskal and Adler, 1997; Navarro, 2006). One way is to suppress the oxygen level to a value that is lethal for insect pests. A low-oxygen control atmosphere can be achieved by applying low pressure (vacuum) to infested commodities (Phillips, 2006). Insect mortality depends on the value of vacuum, exposition time, temperature and also on pest species and their developmental stages. Generally, lethal environment for insect pests starts with O_2 content below 4.5 - 3% (Navarro, 1978; Phillips

and Throne 2010); the less amount of O_2 is present the better is the lethal efficiency to the most insect pests. On the other hand, some residual oxygen content still remains in the controlled commodities when using a vacuum packing machine.

The aim of the present preliminary study was to find out if the addition of an oxygen absorber can remove the residual oxygen content and improve the efficacy of vacuum on mortality of stored product pests for perspective use in CA, MA storage application technology by small organic farmers in the Czech Republic.

The effect of vacuum (V) and vacuum in combination with the chemical absorber ATCO 400 (V+A) on the mortality of *S. granarius* L. adults was compared in laboratory experiments in dependence on temperature, exposition time and vacuum value achieved by vacuum packing machine.

MATERIALS AND METHODS

Laboratory cultures of *Sitophilus granarius* L. (Curculionidae) were maintained in a rearing room at 25ºC and 75% relative humidity on grain cultivar Vánek (CZ).

The effect of the vacuum (V) and combination of vacuum and chemical absorber ATCO 400 (V+A) on beetle mortality was compared in relation to temperature (15 and 25ºC), and duration of exposure (24 to 168 hours) at a constant vacuum value (1.5 kPa). Airtight aluminium and polyethylene film bags (size 10x25 cm) were used for the laboratory experiments. Each bag contained 10-ml plastic vials with 50 beetles (age 1-2 weeks). The vials were closed with permeable caps. Seven replicates were used for each treatment, including the control samples. In V+A treatment one absorber ATCO 400 and 1 tablet of oxygen indicator were added in each bag just before sealing.

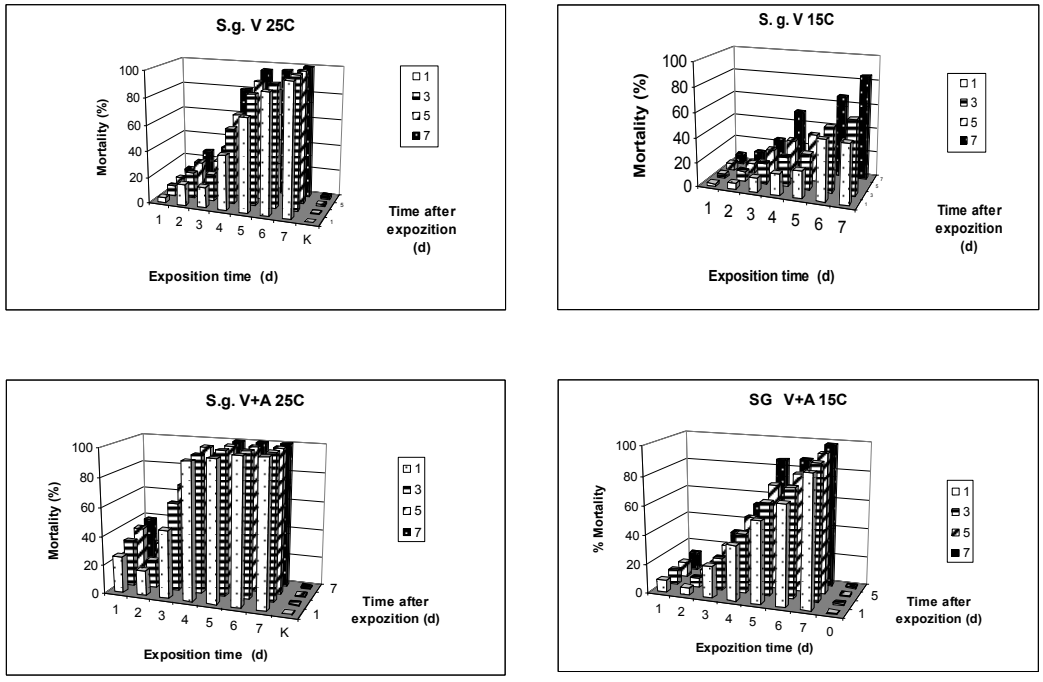
The bags were sealed using a vacuum packing machine (KOMET Vacuboy, KOMET Vakuumverpackungs-maschinen, Plochingen, Germany) and subsequently placed in incubators that were maintained at different temperatures for various exposure times. At the end of each exposure period, the vials were removed from the bags, supplied with a minimum amount of feeding substrate, placed in desiccators (75% r.h.) and returned to the incubators at the appropriate temperature. The mortality of the experimental and control beetles were checked on day 1, 3, 5 and 7 after the ending of exposure to the vacuum. The results were analysed by the logistic regression mortality model (χ^2 – test) for LT_{50} and LT_{99} using the statistical program XLSTAT (Addinsoft France, Paris, France). Statistical analyses were based on the mortality data obtained on day 7 after the ending of vacuum exposure. Non-parametric Nann-Whitney U test was used for statistical comparison of V and V+A treatments after the 1, 4 and 6 days of exposition and comparison of temperature influence (statistical program Statistica 10, StatSoft CR s.r.o, Czech Republic).

RESULTS AND DISCUSSION

VACUUM (V)

S. granarius adults´ mortality is shown in Figures 1A, B and regression models in Fig. 2A, B. Higher temperature significantly increased the mortality of the tested beetles (Z=2.81, p=0.005, 96 h exposition time; Z = 3.07, p = 0.002, 168 h exposition time) and simultaneously decreased the exposition time in vacuum. The lethal times were 74 (LT_{50}) and 160 h (LT_{99}) for V exposure at 25ºC, and 113 (LT_{50}) and 275 h (LT_{99}) at 15ºC (Table 1).

A B



C D

Fig. 1- Mortality comparison of *S. granarius* adults exposed to Vacuum (V) and Vacuum with oxygen Absorber (V+A) in dependence on temperature.
(A - V 25ºC, B - V 15ºC, C - V+A 25ºC, D - V+A 15ºC).

VACUUM AND ABSORBER (V+A)

The absorber lowered the residual oxygen to < 0.1%, which was indicated by the pink colour of the indicator tablets in all tested bags. *S. granarius* adult's mortality is shown in Figs. 1C, D and regression models in Fig. 2 C, D. Higher temperature also significantly increased the mortality of the tested specimens ($Z = 2.81$, $p=0.005$, 96 h exposition time; $Z = 3.17$, $p = 0.03$, 168 h exposition time) and decreased the needed exposition time of modified atmosphere. The lethal times were 48 (LT_{50}) and 142 h (LT_{99}) for V+A exposure at 25ºC and 90 (LT_{50}) and 200 h (LT_{99}) at 15ºC (Table 1).

Table 1. Regression model parameters´ of vacuum (V) and vacuum + absorber (V+A) efficiency on mortality of *Sitophilus granarius*

			Model parameters		Lethal time (h)		Model fitness		
		n	Intercept±SE	Slope±SE	LT50 (95% CL)	LT99 (95% CL)	$\chi 2$	df	P
V	15°C	7	-3.22±0.14	0.03±0.01	112.67 (109.20-116.22)	274.68 (261.15-290.64)	768.47	1	<0.0001
V	25°C	7	-3.98±0.18	0.05±0.01	73.76 (71.36-76.10)	160.10 (153.63-167.63)	1494.30	1	<0.0001
V+A	15°C	7	-3.76±0.16	0.04±0.01	89.91 (87.24-92.54)	200.43 (192.40-209.70)	1278.53	1	<0.0001
V+A	25°C	7	-2.42±0.15	0.05±0.01	48.44 (45.62-51.09)	142.32 (135.06-150.94)	1049.46	1	<0.0001

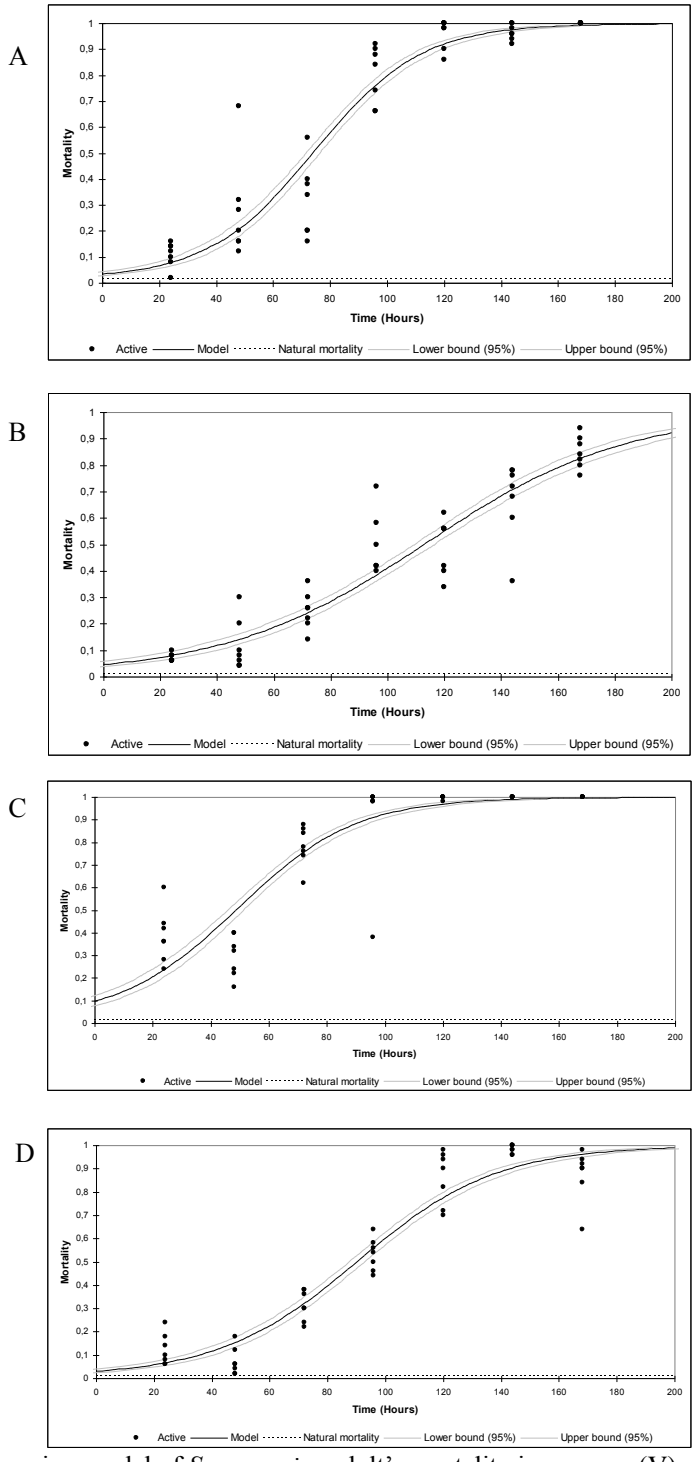


Fig. 2- Regression model of *S. granarius* adult's mortality in vacuum (V) and vacuum with oxygen absorber (V+A)(A - V 25ºC, B - V 15ºC, C - V+A 25ºC, D - V+A 15º).

According regression model the addition of oxygen absorber to the vacuum (V+A) increased the insects mortality in both temperatures and shortened the treatment exposition time by 18 – 74 h. Statistically significant differences in the efficiency between both treatments (V+A and V) were found for the higher temperature (25ºC) in all tested exposition times ($Z = -3.07$, $p = 0.002$, 24 h; $Z = -2.17$, $p = 0.03$, 96 h; $Z = -2.17$, $p = 0.03$, 144 h exposition time). Statistically significant difference at low temperature (15ºC) was in 144 h exposition time only ($Z = -3.07$, $p = 0.002$, 144 h).

The fact, that both tested treatments of MA were more efficient at higher temperatures corresponded with the published results obtained for CA, MA and chemical fumigants (Phillips and Throne, 2010). Higher efficiency of treatments at higher temperatures is connected with more intensive respiration and metabolism of insect.

It is known that the active developmental stages of insects are generally more sensitive to hypoxia (adults, larvae) than inactive stages (eggs, pupae) (Hoback and Stanley, 2001). Particular developmental stages have different respiration rates at reduced oxygen levels (Emekci et al., 2002). The continuing research on comparison of the V and VA effect concerning various developmental stages of *S. granarius* in grain samples is therefore in progress.

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