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The effect of acclimation on heat tolerance of *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae)

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ABSTRACT

Lasioderma serricorne (Fabricius) (Coleoptera: Anobiidae) is an important economic insect of various stored products worldwide. With the restricted use of methyl bromide and the increasing negative effects of repeated use of phosphine fumigation, heat treatment becomes the main approach to control stored-product insects. We investigated effect of the acclimation to sublethal high temperature of 36 °C and 42 °C for different times on heat tolerance of *L. serricorne* adults, pupae, larvae, and eggs to lethal high temperature of 50 °C in laboratory. The acclimation of *L. serricorne* pupae, larvae, and eggs, but not adults, to 36 °C improved their survival when exposed to lethal high temperature of 50 °C. The acclimation of all life stages of *L. serricorne* to 42 °C significantly improved their survival when exposed to 50 °C. For eggs, larvae, and adults, the protective effectiveness of acclimation to 42 °C was much more profound than that of to 36 °C. LT_{50} and LT_{90} of all life stages increased with increasing acclimation time to 42 °C in general. The LT_{50} of *L. serricorne* adults, pupae, larvae, and eggs acclimation to 42 °C for 20 h were 2.2, 2.2, 3.4, and 4.8 times higher than that of insects without acclimation, respectively. The results suggest that acclimation to sublethal high temperatures can significantly improve the heat tolerance of *L. serricorne* by the means of increasing their survival when confronting lethal high temperatures. In the face of global warming, the protective effects induced by acclimation to sublethal high temperatures should be fully considered when design or apply heat treatment to control *L. serricorne*.

1. Introduction

The cigarette beetle, *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae) was an important economic insect worldwide that infests various stored products (grain, spices, herbs, dried fruits, foods and tobacco etc.) (Abdelghany et al., 2016), plant or animal specimens (Querner, 2015), or rarely, human baby (Sun et al., 2016). Control of *L. serricorne* and other stored-product insects has long been relied on methyl bromide and phosphine fumigation (Hill, 1977; Rajendran et al., 2004). However, since methyl bromide has been phased out due to its ozone depleting potential (Gareau, 2015), the phosphine becomes the only chemical tool to control *L. serricorne*. However, as other chemical pesticides, the intensive and repeated phosphine treatment inevitably brings many negative effects, such as resistance, residue, human safety, and environment pollution (Rajendran and Narasimhan, 1994; Anonymous, 1998; Popp et al., 2002). Thus, development of other environmental friendly, safe, and effective strategies is urgent for the control of *L. serricorne* in the near future.

Temperature is one of the important environmental components that determine the distribution and population dynamics of small ectotherms such as insects. Using high temperatures (heat treatment) to control insects, especially for stored product insects, has been widely studied (Fields, 1992; Fields and White, 2002; Yu et al., 2011; El-Naggar and Mikhaiel, 2011; Campolo, 2013). Many studies showed that preexposure to lower sublethal high temperatures for certain times (acclimation) could enhance the heat tolerance of insects when treated with high lethal temperatures (Dahlgaard et al., 1998; Overgaard et al., 2011; Huang et al., 2007; Lachenicht et al., 2010; Li et al., 2011; Alford et al., 2012; Hu et al., 2014; Lü and Zhang, 2016; Muñoz-Valencia et al., 2016; Scharf et al., 2016; Pieterse et al., 2017). Therefore, for the management of stored-product insects, the disinfestation effectiveness of heat treatment might be impaired due to the protective effects induced by acclimation to the sublethal high temperatures during the heating process (Lü and Zhang, 2016).

In this study, we investigated the effect of the acclimation to sublethal temperature of 36 °C and 42 °C, which would be inevitably

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Table 1
Time-mortality probit regression estimates and lethal time values for eggs of L. *serricorne* with acclimation to 36 °C and 42 °C when exposed to 50 °C.

Acclimation temperature (°C)	Acclimation time (h)	N[a]	Intercept ± SE	Slope ± SE	LT_{50} (95% CL) (min)	LT_{90} (95% CL) (min)	Chi-square (df)	*P*-value
–	0	445	0.252 ± 0.042	−2.713 ± 0.604	10.764(8.648–12.126)	15.849(14.612–17.524)	1.281(13)	0.999
36	1	456	0.126 ± 0.012	−1.338 ± 0.178	10.619(8.887–12.285)	20.793(18.629–23.689)	9.530(13)	0.732
	5	453	0.065 ± 0.005	−1.079 ± 0.129	16.513(13.990–18.927)	36.127(32.787–40.417)	13.355(13)	0.421
	10	450	0.083 ± 0.007	−1.424 ± 0.155	17.114(14.964–19.221)	32.521(29.642–36.248)	3.903(13)	0.992
	15	464	0.107 ± 0.010	−1.474 ± 0.165	13.816(12.005–15.638)	25.829(23.333–29.137)	6.545(13)	0.924
	20	464	0.115 ± 0.011	−1.363 ± 0.166	11.859(10.096–13.605)	23.008(20.664–26.130)	6.219(13)	0.938
42	1	445	0.042 ± 0.004	−1.171 ± 0.124	27.621(24.397–30.790)	57.843(52.708–64.681)	12.734(13)	0.469
	5	445	0.038 ± 0.003	−1.211 ± 0.124	31.558(28.139–35.065)	64.960(58.871–73.276)	15.825(13)	0.259
	10	453	0.031 ± 0.03	−1.157 ± 0.120	37.360(33.299–41.889)	78.735(70.024–91.435)	11.688(13)	0.553
	15	493	0.024 ± 0.003	−1.176 ± 0.116	48.234(42.708–55.765)	100.806(86.670–123.622)	9.089(13)	0.766
	20	469	0.023 ± 0.003	−1.170 ± 0.119	51.913(45.501–61.237)	108.773(92.073–137.096)	5.315(13)	0.968

[a] Total number of insects exposed, the same as below tables.

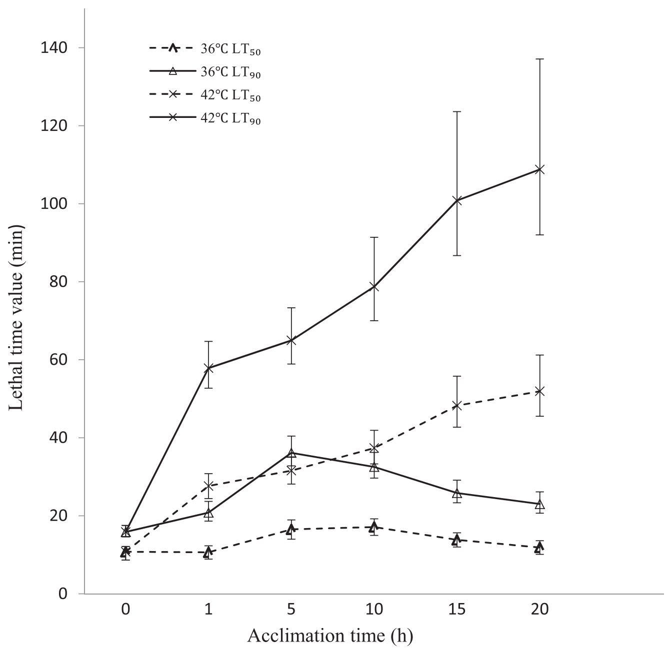

Fig. 1. Effects of acclimation to 36 °C and 42 °C on the LT_{50} (mean ± 95% CLs) and LT_{90}(mean ± 95% CLs) of eggs of *L. serricorne* exposed to 50 °C.

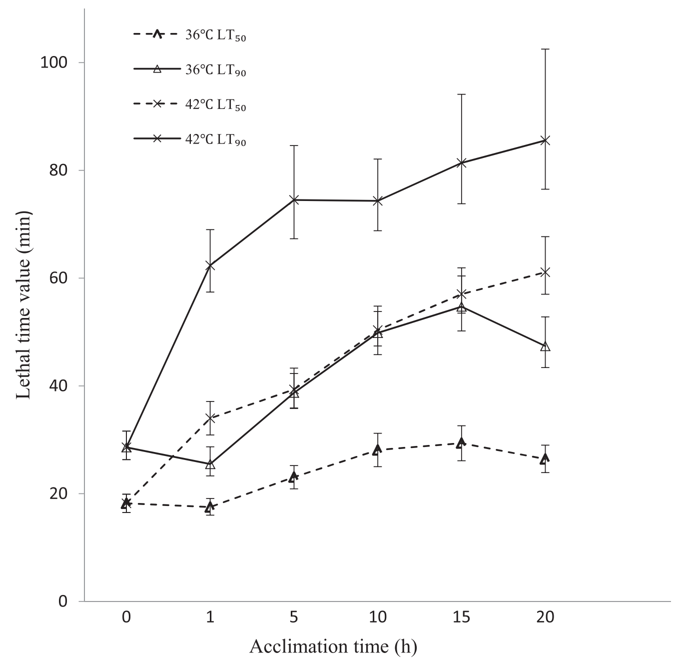

Fig. 2. Effects of acclimation to 36 °C and 42 °C on the LT_{50} (mean ± 95% CLs) and LT_{90}(mean ± 95% CLs) of larvae of *L. serricorne* exposed to 50 °C.

experienced by stored-product insects during heat treatment for disinfestation, on heat tolerance of *L. serricorne* adults, pupae, larvae, and eggs to the minimum heat treatment temperature of 50 °C (Mahroof et al., 2005). Our results would provide helpful information on developing effective control methods based on heat treatment and understanding the role of thermal plasticity played in coping with heat stress in *L. serricorne*.

2. Materials and methods

2.1. Insects

Cultures of the *L. serricorne* were maintained in an artificial environmental chamber at 27 ± 2 °C, 75 ± 5% r.h., and a 12:12 light:

Table 2
Time-mortality probit regression estimates and lethal time values for larvae of *L. serricorne* with acclimation to 36 °C and 42 °C when exposed to 50 °C.

Acclimation temperature (°C)	Acclimation time (h)	N[a]	Intercept ± SE	Slope ± SE	LT_{50} (95% CL) (min)	LT_{90} (95% CL) (min)	Chi-square (df)	*P*-value
–	0	453	0.123 ± 0.012	−2.244 ± 0.242	18.201(16.481–19.912)	28.594(26.331–31.618)	4.976(13)	0.976
36	1	442	0.161 ± 0.019	−2.810 ± 0.343	17.508(15.994–19.117)	25.492(23.327–28.678)	4.648(13)	0.982
	5	438	0.812 ± 0.007	−1.888 ± 0.184	23.062(20.851–25.217)	38.720(35.873–42.326)	14.906(13)	0.313
	10	453	0.059 ± 0.005	−1.656 ± 0.159	28.092(24.976–31.178)	49.832(45.832–54.809)	8.546(10)	0.576
	15	462	0.051 ± 0.004	−1.486 ± 0.143	29.369(26.118–32.608)	54.706(50.231–60.400)	12.898(10)	0.229
	20	462	0.061 ± 0.005	−1.614 ± 0.158	26.414(23.929–28.972)	47.388(43.375–52.791)	13.158(10)	0.215
42	1	444	0.450 ± 0.004	−1.535 ± 0.142	33.977(30.944–37.069)	62.352(57.351–68.965)	12.292(13)	0.504
	5	459	0.036 ± 0.003	−1.434 ± 0.134	39.340(35.790–43.294)	74.503(67.320–84.616)	10.654(13)	0.640
	10	455	0.053 ± 0.005	−2.692 ± 0.232	50.352(47.369–53.846)	74.326(68.771–82.104)	15.901(13)	0.255
	15	459	0.053 ± 0.007	−3.001 ± 0.358	57.026(53.523–61.882)	81.377(73.819–94.052)	11.837(10)	0.296
	20	450	0.052 ± 0.008	−3.201 ± 0.428	61.089(57.014–67.650)	85.547(76.489–102.461)	9.896(7)	0.195