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Development of the Red Flour Beetle *Tribolium castaneum* (Herbst) at a Reduced Oxygen Atmosphere

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Abstract: In the present study, the development of the red flour beetle Tribolium castaneum (Herbst) was conducted at 10% oxygen in nitrogen. The length of survival of the various stages of the insect, were recorded. Following a statistical analysis, , the results indicated that at 10% oxygen atmosphere can suppress the development of red flour beetles effectively, especially the egg and the larva. But the pupa stage showed more tolerance to reduced oxygen atmosphere. By comparing the amount of males and females we can conclude that the female red flour beetle is more sensitive to the reduced oxygen atmosphere than the male.

Key words: red flour beetle, reduced oxygen atmosphere, development, survival

Introduction

Controlled atmosphere (CA) disinfestation technology involves the alteration of the proportions of the natural storage gases – CO_2, O_2 and N_2 to render the atmosphere in the stores unfavorable to pests. CA does not involves use of fumigants such as phosphine or methyl bromide, nor alteration of the humidity and temperature of the environment [1].

Most researchers have concentrated on the acute mortality effect on insects under a low concentration of oxygen, and obtained a satisfactory results that a prolonged low oxygen atmosphere can kill most stored grain insects. [2,3,4] However, the sub lethal effects of CAs on insects, such as delayed development, impaired metamorphosis and altered fecundity, have not been well documented [3]. It is possible to arrest insect pest development and minimize damages [4,5]. Information on insects under a low oxygen atmosphere development is important, since this information can be referred to a number of ways such as calculating and deciding the sealing time in a field treatment of CA.

Reports indicate that insect development under a low oxygen concentration atmosphere is slower and weaker as compared with those developed in a normal atmosphere[6]. Spratt (1979) reported that under an atmosphere of 10% O_2, 10% CO_2 and 80% N_2, the development of maize weevil was about 10 – 11 days longer than the normal one [7].

As an important stored grain insect, the development of the red flour beetle can cause serious damage. The present study was carried out to study the development of the red flour beetle at a reduced oxygen atmosphere.

Materials and Methods

Insect Culture

About 500 – 800 adult red four beetles were placed in several 1 L jars which contained approximately 300 g of flour and 5% yeast (by weight). Every three days the jars were sieved for eggs removal. The adults were kept for oviposition for up to one month.

Experimental method

Gas mixing equipment is shown in Fig. 1. The development of the red flour beetle was carried out in atmospheres containing 10 1% O_2 by volume with N_2 as a balance at 30℃. The flow rates of O_2 and N_2 were 180 mL/h and 1600 mL/h respectively. Normal air atmosphere served as control.

The red flour beetle eggs were obtained from 2000 adults placed in 1 L jars that contained approximately 300 g of flour and 5% yeast (by weight). After one day of oviposition, the jars were sieved for egg removal.

The egg exposure device was constructed of plastic; the height and diameter were 8 mm and 100 mm respectively. A plate with 54 holes (diameter of 5mm). was glued on the bottom of each device to prevent insect escaping. The

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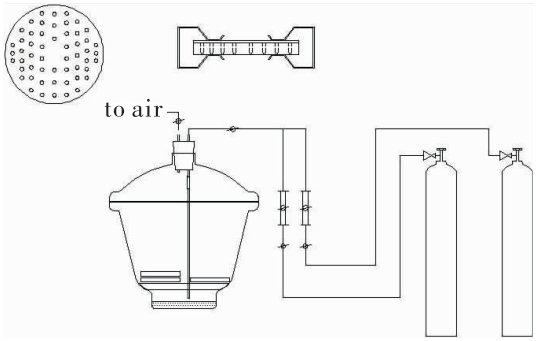

Fig. 1 **the experimental equipment**

eggs were placed one by on in each hole.

The treated and control group both contained 3 devices with eggs for each replicate. After putting them in the relevant desiccators which contained saturated NaCl solution to create a 75% relative humidity at 30℃, the desiccators were sealed and the atmosphere of treated group were modified and the concentration of oxygen was measured by gas chromatography.

After 24 h exposure, the insects were checked by using a binocular microscope.

Results

Insect Development

Table 1**. Development times required for the three life stages of the red flour beetle at** 10% O_2 **and** 30℃**.**

Stage	Group	(%)	Period (d)	p – value for period
		Hatching ratio		
egg	treated	69.0	4.13 ±0.47	0.0007
	control	79.6	3.96 ±0.26	
		Pupation ratio		
larva	treated	31.5	48.17 ±13.98	0.0076
	control	43.0	41.51 ±9.41	
		Emergence ratio		
pupa	treated	80.0	5.79 ±0.74	0.4042
	control	96.0	6.02 ±1.37	

Observation on 162 eggs placed in both treated and control group showed that 111 eggs hatched in the treated group, and 129 eggs hatched in the control group. The egg hatch ratio of treated group was 69.0%, and in the control group was 79.6%. This indicates that an atmosphere of 10% oxygen concentration has suppressing affect on egg hatch of the red flour beetle.

The average development period of egg stage in the treated group (4.13 ± 0.47 d), was longer than the control group (3.96 ± 0.26d) in. P – values = 0.0007 < 0.05 indicated that low oxygen atmosphere can effectively prolong the period of egg development of the red flour beetle.

There were 35 larvae pupating in the treated group containing 111 larvae. There were 56 larvae pupating in the control group containing 129 larvae. The pupation ratio of the treated group was (31.5%) lower than in the control group (43.4%). This indicates that an atmosphere of 10% oxygen can suppress the pupation ratio of the red flour beetle.

The average development period of the larval stage in the treated group was (48.17 ± 13.98d) longer than in control group (41.51 ± 9.41 d). P – values = 0.0076 < 0.05 indicated that a low oxygen atmosphere can effectively prolong the period of larval development of the red flour beetle.

There were28 pupae that emerged e in the treated group, and 54 pupae that emerged in the control. The emergence ratio of treated group was (80.0%) lower than in the control group (96.0%). This indicates that an atmosphere of 10% oxygen concentration can effectively suppress the red flour beetle emergence.

The average development period of the pupal stage in treated group was (5.79 ± 0.74 d) shorter than n the control group (6.02 ± 1.37 d). But the P – values = 0.4042 > 0.05 indicated that low oxygen atmosphere did not affect pupal development period of the red flour beetle.

Sex Ratio

In the treated group, 29 pupae emerged.

There were 7 females and 22 males, 25% and 75% of the total amount individually, which indicates a sex ratio of approximately 1: 3. In the control group, the number of females and the males were 25 and 29 individually, 46% and 54% of the total amount of emergence respectively, which indicated a sex ratio of about 1: 1.

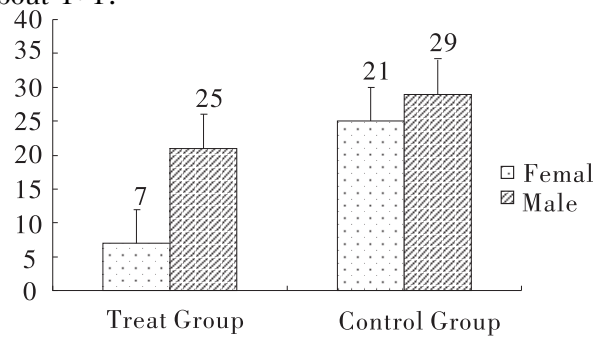

Fig. 2 **Variations of sex ratio between treated** (10% O_2) **and control groups at** 30℃

These results indicate that if the red flour beetle can survive and develop in a a reduced oxygen concentration atmosphere, more females will be killed before reaching the adult stage, than males. , This indicates the female is more susceptible than the male, and that a low oxygen atmosphere obviously has an cumulative lethal effect on the female red flour beetle.

Discussion

According to the comparison of the development periods in the treated and control group, there was a prolonged egg and larval period in the treated group. The approximate length of the pupal period in both groups showed a significant resistance of pupae under the reduced oxygen concentration atmosphere in comparison with the other two stages which was already shown in previous research[8,9]. The above differences can be explained by the pupa which is in a static stage of metamorphosis. This stage is considered as a less energy demanding period. Thus a relatively low respiration rate could affect the need for oxygen. Contrarily, the egg stage which is also a static stage during metamorphosis was more susceptible than pupae in this study.

The explanation may be found in the work of Emekci et al. , (2002) who showed that the RQ in a 10% oxygen atmosphere for the red flour beetle egg, larva and pupa were 0. 96, 1. 00 and 0. 78, respectively. This reflects a protein-carbohydrate metabolism for egg, carbohydrate metabolism for larva and protein-lipid metabolism for pupa [10]. Lipid is an effective energy resource; a complete lipid metabolism can produce 129 ATP, which is more than by carbohydrate or protein metabolism. , The lipid metabolism of pupae probably ensures its survival in a reduced oxygen atmosphere, without being significantly affected by the lack of oxygen.

During the present study, the female of the red flour beetles showed a higher sensitivity than the males, from which we can conclude that there are some dissimilarities in development between the sexes of red flour beetle in a reduced oxygen atmosphere. Further research is needed to explain these results.

In the treated group, unusual moulting of the larva was observed. Skin separation from the tail was earlier compared to control. It was also observed that many old instar larvae remained with a smaller body size compared with the control. More research on the impact of a reduced oxygen atmosphere on tissue development, endocrine system and cell development is needed.

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