CHAPTER 7

QUANTITATIVE CHANGES OF FAT AND GLYCOGEN DURING METAMORPHOSIS IN *TROGODERMA GRANARIUM*

From the results presented in the previous chapter it is evident that fat and glycogen are stored in the fat body and serve as the source of energy during diapause. Studies of Pepper and Hastings (1943), Ludwig and Rothstein (1949), Levinson and Silverman (1954), Demyanovsky and Zubova (1957) (c.f. Domroese and Gilbert, 1964), Gilbert and Schnedierman (1961), Villeneuve and Lemonde (1963), Barlow (1964), Domroese and Gilbert (1964), George and Nair (1964) and Schmidt (1966) showed that in several insects the levels of fat and glycogen decrease during the pupal-adult transformation. A difference between the sexes in the utilization of fat was noted in the giant silk worm, *Hyalophora cecropia* (Domroese and Gilbert, 1964). The female utilized lipids continuously throughout the pupal-adult transformation while the male showed a lipid sparing metabolism. Though a study of the levels of fat and glycogen during metamorphosis of a related dermestid beetle, *Anthrenus vorax* was reported by George and Nair (1964) no attempt was made in their study to analyse the sexes separately. A quantitative study of the changes in fat and glycogen in both the sexes, during metamorphosis was therefore undertaken. The changes in the body weight and water content were also studied.

MATERIAL AND METHODS

Different stages of metamorphosis were obtained from cultures maintained on crushed wheat at 35±1°C and 70% R.H. within 12 hr of their entry into that particular stage. Sexes were separated at the pupal stage with the help of the rudiments of genitalia.

Estimations of Fat and Glycogen

For estimations of fat and glycogen, batches of fifty insects were used. The method employed was as described in Chapter 4.

RESULTS

The changes in body weight and the presentation of results

The mean body weight of the female pupa was found to be 3.77 mg. The male pupa showed a mean body weight much less than that of female (1.53 mg). During metamorphosis there was a gradual decrease in the body weight of both sexes (Fig. 1). Of the initial pupal weight the pre-emergent adult had lost 0.223 and 0.225 mg for male and female respectively. The newly emerged adult weighed 0.447 and 0.515 mg laess respectively for male and female than the first day pupa. It may be noted that the loss in weight per insect, in absolute amounts, from the first day pupa to the newly emerged adult differed only slightly in the male and female (0.447 and 0.515 respectively). But expressed as percentage loss of the initial pupal weight

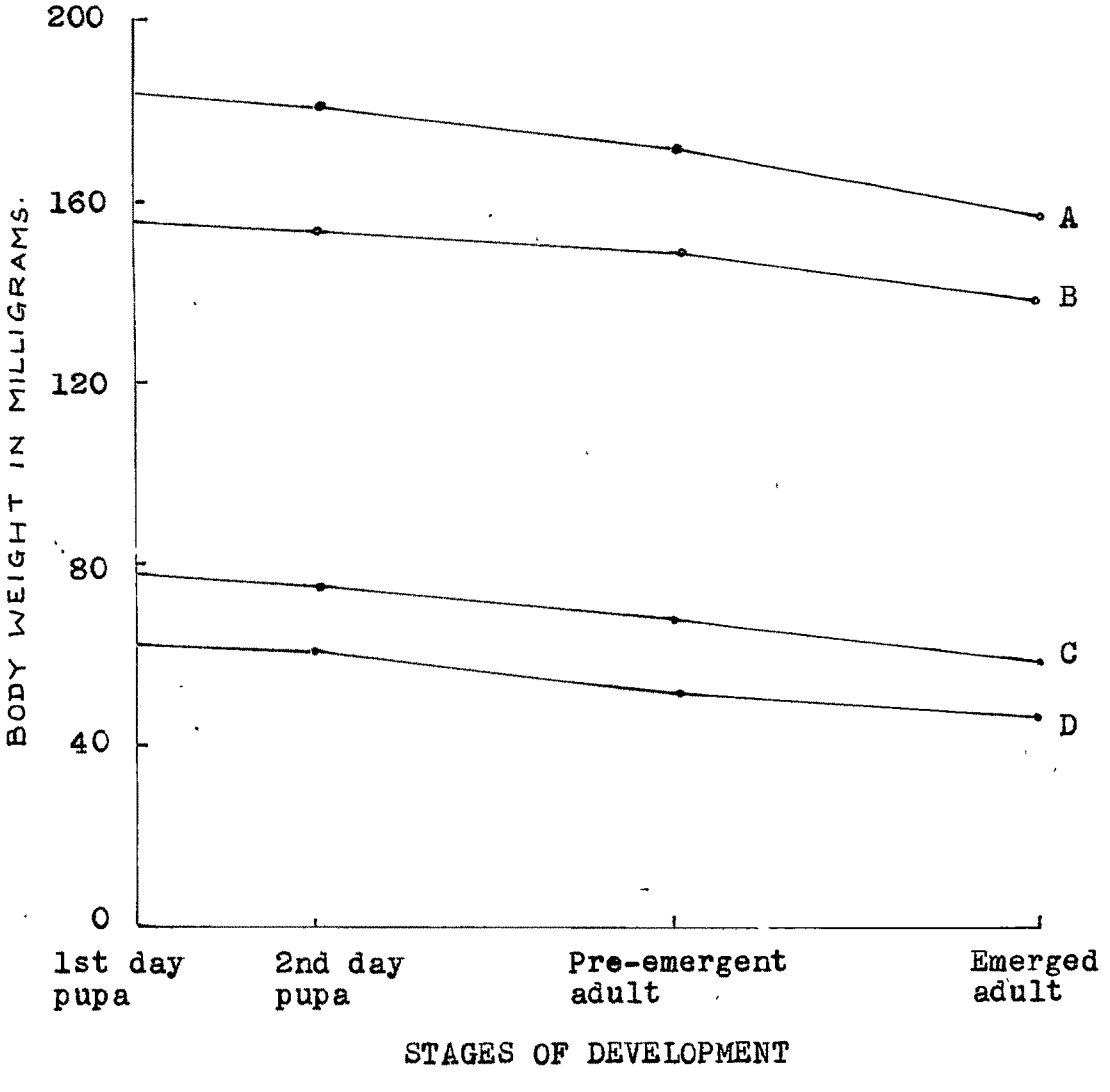

Fig. 1. Showing the changes in body weight of T. granarium during metamorphosis.

A and B, the changes in the total body wt of 50 and 40 female pupae respectively during metamorphosis.

C and D, the changes in the total body wt of 50 and 40 male pupae respectively during metamorphosis.

(28.78% for the male and 13.68% for the female) the difference was more striking.

The significant changes in body weight during metamorphosis necessitated some correction in the expression of the data obtained on the fat, glycogen and water contents. When the amounts of fat, glycogen and water in the different stages of metamorphosis are expressed as percent body weight, the concomitant reduction in the body weight itself has an important effect in modifying the percentages. To illustrate, assuming that a given numder of males weigh 100 mg as first day pupa, because there was a 30% reduction (approximately) of the body weight during metamorphosis, the same lot would weigh only 70 mg in the first day adult stage. Now, if we assume for the sake of argument that the fat content was 20 mg in the first day pupa and that it remained unchanged during metamorphosis, the fat content expressed as percent body weight ~~body~~ would be 20% in the first day pupa and 28.6% in the first day adult. Thus it may be noted that the percentage values would show an increase in the fat content when there has been no change in the absolute amount of fat.

A better way of expressing the results would be to give the weight of a particular component per a definite number of individuals. But here, a correction has to be made to account for the difference in the size and weight between the male and female on the one hand and amongst the individuals themselves of either sex on the other. Therefore, the weight

of a particular component per 100 insects has been calculated based on the standardized weight of 100 insects. The standardized weight were obtained from the actual data on the weight of the insects at different stages of metamorphosis (Fig. 1). Thus the amount in milligram of glycogen per 100 pupae is the amount calculated per 376.7 mg weight for the female and per 155.3 mg weight for the male. In the actual determination the weight of 100 pupae may have been more or less than the standardized weight because of the difference in the body weight among the individuals. To illustrate, the glycogen content of the first day female pupa as expressed above is 4.506 mg per 100 standardized pupae (ie. per 376.7 mg body weight) which in the actual determination represented the value for 101.4 pupae. Similarly the glycogen content of the first day male pupa is presented as 1.477 mg per 100 standardized pupae (ie. per 155.3 mg body weight) which actually represented the value for 90.72 pupae, because the insects used in this particular determination weighed a little more than the standardised pupae. In the same way, the amount in mg of glycogen per 100 newly emerged adult has been expressed as the amount per 325.2 mg body weight for the female and 110.6 mg body weight for the male. Thus a correction has been applied for the change in the body weight during metamorphosis.

Water content

The first day pupa had a higher water content (59.77% in the female and 56.80% in the male) than the last

instar larva(49.84%). From the first day pupa to the newly emerged adult there was a further increase in the percentage of water content in both male and female (65.22% in female and 61.38% in the male). The female had a higher percentage than the male in all the stages. Though an increase in the percentage of water content during metamorphosis is quite obvious, this was mainly an effect of the decrease in body weight; the absolute water content, expressed as the amount in milligrams per 100 insects shows a reduction in the first day adult male and female.

Fat content

In all the stages the male had a higher percentage of fat than the female. But in absolute amount, because of its large size, the female possessed more than twice the amount of fat present in the male. A significant reduction in the fat content occurred in both the sexes during metamorphosis (Table I). The reduction in the fat content amounted to 24.42 mg per 100 insects and 13.61 mg per 100 insects for female and male respectively, which represent 33.85% and 40.46% respectively of their initial (1st day pupa) fat content. Of this 14.06% and 26.97% (of the initial fat content) for the female and male respectively occurred between the 1st day pupa and the pre-emergent adult and the rest between the latter stage and the newly emerged adult. It is interesting to note that though the female had utilized more fat than the male the amount of fat utilized per unit body weight was more in the male. During the entire period of pupal-adult transformation the females had utilized 6.483 mg

Table. 1. Showing the bodyweight, fat and glycogen contents of Trogoderma granarium during metamorphosis.

		First day Pupa		First day Pre-adult		First day Adult	
		Female	Male	Female	Male	Female	Male
Body weight in mg		3.77	1.55	3.54	1.33	3.25	1.11
Water content	% body wt.	59.71	56.80	64.75	60.59	65.22	61.38
	mg/100 ins.	225.1	88.19	229.4	80.45	212.1	67.89
Fat content	% body wt.	19.61± 2.06	21.66± 1.39	17.56± 1.33	18.50± 1.33	14.68± 1.28	18.11± 1.49
	mg/100 ins.	72.16	33.64	62.01	24.57	47.74	20.03
Glycogen content	% body wt.	1.196± 0.065	0.951± 0.195	1.222± 0.195	0.684± 0.156	0.933± 0.603	0.510± 0.130
	mg/100 ins.	4.506	1.477	4.331	0.908	3.035	0.564

fat per 100 mg of the initial pupal weight whereas the males had utilized 8.764 mg per 100 mg of the initial pupal weight.

Glycogen content

The data obtained are presented in Table I. Both in percent body weight and absolute amounts, the glycogen content was found to be higher in the female in all the stages. In the 1st day pupa the glycogen content amounted to 1.196% of the body weight in the female as compared to 0.951% in the male. In absolute amounts the females pupa had 4.506 mg glycogen per 100 insects and the male only 1.477 mg. A total reduction of 1.471 mg and 0.913 mg of glycogen per 100 insects for the female and male respectively occurred during metamorphosis. These amounts represent 32.64% and 61.81% of the initial glycogen content of the female and male respectively. From the 1st day pupa to the pre-emergent adult there was no significant difference in the glycogen content of the female, but 38.5% of the initial glycogen content was used by the male during this period. From the pre-emergent adult to the newly emerged adult stage, the reduction in glycogen content was more pronounced in the female. As in the utilization of fat, it was found that the amount of glycogen utilized per unit body weight was more in the male. Whereas the male had utilized 0.588 mg glycogen per 100 mg of the initial pupal weight, the female had utilized only 0.391 mg per 100 mg of the initial pupal weight during metamorphosis.

DISCUSSION

It is well documented that insects during metmorphosis show a gradual reduction in body weight. In Trogoderma the loss in body weight amounted to 28.78% and 13.68% of their initial pupal weight in the male and female respectively. The combined loss of water, fat and glycogen during metamorphosis could account for 22.41% and 10.31% for the male and female respectively of the initial body weight. It may be noted that the greater percentage loss in body weight of the male is due to the greater amount of reduction per unit body weight of the water, fat and glycogen contents.

That fat serves as the chief source of energy during metamorphosis of several holometabolous insects is now well established (Gilbert and Schneiderman, 1961; Agrell, 1965). In Trogoderma also there is considerable reduction in the fat content during metamorphosis. Of the lipid reserves in the 1st day pupa 40.46% in the male and 33.85% in the female are utilized, evidently to meet the energy demands during the pupal-adult transformation. The present study also throws light on certain differences in the lipid contents and the patteren of lipid utilization between the male and female. In all stages the male contains a higher percentage of fat. But in absolute amounts the female possesses more than twice the amount in the male, owing to its bigger size. As in the lipid content, in lipid utilization also the same differences were observed. The male utilized a higher percentage of its initial (1st day

pupal) fat content (40.46% in the male compared to 33.85% in the female). However, in absolute amounts the female utilized 24.42 mg fat per 100 insects whereas the male utilized only 13.61 mg per 100 insects. It is interesting to note that the amount of fat utilized per unit body weight is also higher in male - 8.764 mg per 100 mg of the first day pupal weight in male and 6.48 mg per 100 mg of the first day pupal weight in the female. Differences between the sexes also exist in the time of utilization of fat. In the male 66.65% of the total utilization occurs between the 1st day pupa and the pre-emergent adult in the female only 41.56% are utilized during this period.

A difference between the sexes in the pattern of lipid utilization has been also recorded in recent years in certain other insects. Domroese and Gilbert (1964) showed in Hyalophora cecropia that the female utilized her lipid stores continuously throughout the pupal-adult development and during adult life, while in the male the lipids were utilized only during adult life. During the pupal-adult development of the male, the lipid content had remained essentially constant thus showing a lipid sparing metabolism. Demyanovsky and Zubova (c.f. Domroese and Gilbert, 1964) showed in Antheraea pernyi a fall of lipid throughout the development in the female and only a drop in the male till the 16th day of development followed by an increase. In Bombyx, both the sexes have the same quantity of lipid in the pre-pupal stage. The female utilizes about 50% and the male 30% of the initial lipid content (c.f. Domroese and Gilbert, 1964). Domroese and Gilbert have observed that the development in the Lepidoptera shows a

metabolic specialization such that the male of the species is provided with adequate lipid stores for use in the adult stage.

In Trogoderma, though there is a difference between the sexes in the lipid content and the pattern of lipid utilization both sexes utilize lipids during metamorphosis. Further it may be noted that the male contains a higher percentage of lipids in all the stages(though lesser than in the female in absolute amounts), that it utilizes a greater percentage of its initial reserve during metamorphosis and that it also utilizes a greater absolute amount of lipids per unit body weight.

A large percentage of the pupal fat content (about 66% in the female and 59% in the male) remains unutilized in the emerged adult. Since Trogoderma do not feed as adults, this may be utilized to provide energy during adult life. The adult female contains more fat in absolute amounts which would be utilized for incorporation into the eggs formed after emergence.

Glycogen is another important metabolite utilized during metamorphosis either for providing energy or for the synthesis of chitin, or both. Among coleoptera, utilization of glycogen during metamorphosis was reported in several insects such as Popllia japonica (Ludwig and Rothstein, 1949), Anthrenus vorax (George and Nair,1964), and Anthonomus grandis (Nettles and Betz, 1965). In Trogoderma there is a gradual decrease during metamorphosis. The glycogen content amounts

to 4.506 mg per 100 female puape and 1.477 mg per 100 male pupae of which a total reduction of 1.471 mg and 0.931 mg of glycogen per 100, for female and male respectively occured during metamorphosis. This decrease amounts to 32.64% and 61.81% of the intial glycogen contents in the female and male respectively.

A difference between the sexes could be noted in the content and pattern of the utilization of glycogen as was seen in the case of Hyalophora cecropia. In all the stages the female contained a higher percentage as well as a higher absolute amount of glycogen. With respect to utilization during metamorphosis, it may be seen that though the female utilized a higher absolute amount of glycogen (1.471 mg per 100 insects) than the male (0.913 mg per 100 insects), it represented only a smaller percentage of the total glycogen reserve (32.64%) compared to that utilized by the male (61.81%). Here again, a difference between the sexes was encountered at the time of utilization. From the 1st day pupa to the pre-emergent adult there was significant reduction in the glycogen content of the female; most of the reduction occured during the later period. On the other hand in the male 62.38% of the total reduction occurred during the earlier period. As in the utilization of lipids, the amounts of glycogen utilized per unit body weight was found to be more in the male (0.588 mg glycogen per 100 mg of the initial pupal weight in the male and 0.391 mg glycogen per 100 mg of the initial puapl weight in the female).

It should be of interest to note that while the

female utilizes a lesser amount of fat and virtually no glycogen during the first half of the pupal-adult transformation compared to the second half, the male utilizes a greater amount of these metabolites during the first half than the second.