

EFFECT OF DIFFERENT MINERAL SALTS IN FOOD  
ON THE RESPIRATORY METABOLISM OF  
Oryzaephilus surinamensis (L.)  
(Coleoptera: Cucujidae)

By

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A B S T R A C T

The rate of  $O_2$  uptake increased sharply with larval feeding and growth, reaching the highest value on the 12 - 14th day of larval development. Afterwards it declined steeply for prepupal stage. The respiratory pattern during the pupal stage exhibited the U-shaped curve. With the emergence of adult, the rate of  $O_2$  consumption increased slightly for adults 0 - 1 week. The respiratory rates of 0 - 1 and 3 - 4 weeks old adults differed markedly. All the tested salts stimulated larval metabolism. The highest stimulation was recorded for inhibitory salts, especially  $NH_4NO_3$ . Tested salts increased metabolic rates of the prepupae except for  $(NH_4)_3PO_4 \cdot 3H_2O$ . Pupal metabolism exhibited the U-shaped curve. The metabolic curves of pupae reared on 1 % conc. of  $KH_2PO_4$  and  $(NH_4)_3PO_4 \cdot 3H_2O$  were similar in shape to the flattened U-shaped metabolic curve of control pupae. Metabolism of pupae reared on 0.5 % conc. of  $NH_4NO_3$  and  $Ca_3(PO_4)_2$  was more affected and showed typical U-shape curve. In the case of newly emerged adults, tested salts showed the same effect on both sexes. A linear relationship between oxygen consumption and fresh body weight was found for both larvae, and adults.  $NH_4NO_3$  showed the strongest stimulatory effect on the specific metabolism of both larvae and adults.

INTRODUCTION

One of the most important physiological features characterizing food utilization and which is considered a very important indicator of metabolism, is growth respiration. There is a great deal of papers in literature dealing with respiration of stored product insects. To exemplify this let us mention only the names of several authors and objects of their studies: Birch, (1947) - Calandra oryzae L.

and Rhizopertha dominica Fab., Burges, (1960) Trogoderma granarium Everts; Klekowski, et al, (1967) - Tribolium castaneum (Hbst.), Cambell, et al, (1976) Sitophilus granarius (L.), Singh et al, (1976) - Sitophilus oryzae L., Cambell et al, (1978) - Cryptolestes ferrugineus (Stephens) and R. dominica Fab, Baker, et al, (1979) - Attagenus megatoma (F.) Studies on the effect of inorganic salts on oxygen metabolism of O. surinamensis (L.) have not been carried out yet. Therefore, studies were undertaken to determine the respiratory pattern exhibited by O. surinamensis during its postembryonic development. The influence of weight, age and sex (of adult insects) on the respiration of individuals reared on both whole wheat flour and wheat flour mixed with selected stimulatory and inhibitory salts was also tested. A general picture of metabolic activity provided through the postembryonic development. Tested salts were selected as a result of Boczek, J. et al, (in press) study on the effect of mineral salts in the diet on several stored-product insects and mites.  $\text{Ca}_3(\text{PO}_4)_2$  and  $\text{NH}_4\text{NO}_3$  were selected as inhibitory salts while  $\text{KH}_2\text{PO}_4$  and  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  as stimulatory ones.

#### MATERIALS AND METHODS

The original stock cultures of O. surinamensis (L.) were obtained from local warehouses at Poznan. Laboratory cultures of insects were kept on whole wheat flour in 0.5 L glass jars covered with fine mesh nylon screen tops. For several generations. The insects had been reared in darkness at a constant temperature (30 °C) and 75 % R.H. The designed relative humidity was achieved with the saturated solutions of sodium chloride (according to Buxton and Mellanby, 1934). The stock cultures were cleaned and renewed every 2 - 3 months. The salts were ground in porcelain mortar to fine powder and passed through 200 µm sieve. The concentrations were prepared by weighing the desired amount of the salt and adding it to the whole wheat flour. The components were mixed thoroughly for 60 minutes in a ball mixer and then conditioned at 30 °C and 75 % R.H before offering it to the insects.

Oxygen consumption measurements of larvae up to the 4th day of age had been done in Cartesian diver microrespirometer (Grodzinski, et al, 1975). The same measurements for the older larvae, prepupae, pupae and adult stages were done in constant-pressure volumetric microrespirometer for terrestrial invertebrates (Grodzinski, et al, 1975).

Since tricalcium phosphate and ammonium nitrate used at 1 % concentration in food inhibited strongly the population growth of O. surinamensis (Boczek, J., et al, "in press"), therefore it was decided to decrease the concentration of these salts to 0.5 % to get enough material for oxygen consumption measurements.

The oxygen consumption measurements were done every second day for larval stage and every day for pupal stage. The measurements were always made at the same hour, so as to eliminate possible diurnal oscillations in oxygen consumption. In case of adults the measurements were done at 0 - 1 week and 3 - 4 week old adults for both sexes. Experimental adults were held with unified amount of diet in small glass cells, closed with fine nylon net, to prevent the insects from getting into NaOH solution. In such cells insects could move freely. The same cells with diet were kept in the compensation chambers.

All the specimens were weighed after respiration measurements. The data were presented graphically. Each point on the graphs or each mean in the tables is the average of at least 10 measurements.

The relationship between  $O_2$  consumption and fresh body weight was calculated as the regression

$$QO_2(R) = a \cdot W^b$$

where:

$QO_2(R)$  : oxygen consumption in  $\mu l$  per hr per average specimen;

$W$  : fresh body weight in  $\mu g$  of average individuals;

$a=R/W^b$  : is approximately constant and represents the specific metabolism. This value depends on the units used to measure  $R$  and  $W$ ;

$b$  : regression coefficient which define the slope of the regression line on a log-log scale and is expressed by the tangent of the angle formed by the regression line with the absissa. The value of  $b$  is independent of the units of  $R$  and  $W$  and is a constant for a given regression (Grodzinski, et al., 1975).

## RESULTS AND DISCUSSION

The effect of different mineral salts on the respiratory rates ( $\mu l O_2$ /ind. hr) of *O. surinamensis* postembryonic developmental stages is presented in tables 1 - 5.

As seen in table 1, the rate of  $O_2$  uptake increased sharply with larval feeding and growth reaching the highest value  $6.068 \mu l O_2$ /ind. hr, on the 12th day of larval development. Afterwards it declined steeply to  $0.997 \mu l O_2$ /ind. hr, for prepupal stage. The respiratory pattern during the pupal stage exhibited U-shape curve starting with  $0.878 \mu l O_2$ /ind. hr, for 1 day old pupae and decreasing to its minimum level,  $0.475 \mu l O_2$ /ind. hr, on the 4th day and then increasing again to  $0.655 \mu l O_2$ /



ind. hr. With the emergence of adult, the rate of  $O_2$  consumption increased slightly for adults 0 - 1 week. The respiratory rates of 0 - 1 and 3 - 4 weeks old O. surinamensis adults differed markedly. The highest values were recorded for females 3 - 4 weeks old, 10,453 ul  $O_2$ /ind. hr.

Similar pattern of  $O_2$  consumption was showed by O. surinamensis individuals reared on whole wheat flour mixed with selected stimulatory and inhibitory salts. It can be concluded from the above mentioned results that larvae and adults consumed more oxygen than other stages. Oxygen consumption increased sharply with larval feeding and growth, reaching its highest value on 12 - 14 days after egg hatching. The only exception was found for larvae fed on diet mixed with TCP. In this salt the highest value of  $O_2$  uptake was recorded on the 10th day of larval development. Afterwards the rate of  $O_2$  consumption declined sharply, especially in the case of 1 %  $KH_2PO_4$  and  $(NH_4)_3PO_4 \cdot 3H_2O$ .

On the other hand respiration in adult beetle varied between sexes and within each sex according to the age of the insect. Adults 3 - 4 weeks old consumed more oxygen than younger ones. Females also consumed more  $O_2$  than males. This obvious increase in respiratory rates can be attributed to their high activity in comparison to larvae. The high differences between oxygen consumption of younger and older adults, especially with females, can also be attributed to both weight factor and reproductive activity. The above mentioned results of O. surinamensis are partially in agreement with those of Singh, et al, (1976) who found that the rate of oxygen consumption of S. oryzae reared on wheat flour increased with larval growth reaching the highest value on the 15th day of development when an individual consumed 438.0 ul/ $O_2$ /day. Afterwards the rate of  $O_2$  consumption declined sharply. They recorded an extremely low rate of  $O_2$  consumption on the 22nd day, when the pupal stage was formed. With adult emergence the rate of  $O_2$  consumption increased slightly. The respiratory rates of 0 - 1 and 2 - 3 week old S. oryzae adults did not differ markedly.

### Metabolic Activity :

#### Larval metabolic activity:

Data presented in fig. 1, show the effect of 1 % conc. of both  $(NH_4)_3PO_4 \cdot 3H_2O$  and  $KH_2PO_4$  on larval metabolic rates. In control, the oxygen consumption per mg fresh body weight was 10 ul  $O_2$ .hr for 1 day old larvae. This value increased slightly in the 2nd day and then decreased to 8.100 ul  $O_2$ /mg.hr, in larvae 4 day old. A sharp increase was recorded in the metabolic rate on the 6th day followed



by a slow and slight decrease till 12th day when steep decrease was recorded. On the other hand,  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  increased the highest value of larval metabolic rate from 27.231  $\text{ul O}_2/\text{mg.hr}$  (under control condition) to 39.638  $\text{ul O}_2/\text{mg.hr}$ ; then lowered it in comparison to control at 8, 10 and 12 day old larvae. Data presented in metabolic curve of O. surinamensis larvae reared on 1 % conc. of  $\text{KH}_2\text{PO}_4$  indicated that this salt increased the  $\text{O}_2$  consumption per mg of fresh body weight. The highest value, 45,222  $\text{ul O}_2/\text{mg.hr}$ , was recorded in the 8th day old larvae, followed with steep decrease to the end of the larval stage. These observations suggest that as O. surinamensis larvae grew and developed, their metabolic activity increased to certain level and then an inverse relationship between the metabolic rate and larval age was recorded.

As shown in fig. 2, both selected inhibitory salts ( $\text{NH}_4\text{NO}_3$  and  $\text{Ca}_3(\text{PO}_4)_2$  at 0.5 % conc.) stimulated strongly the metabolic activity of larvae. Larvae reared on diet with  $\text{NH}_4\text{NO}_3$  respired more efficiently than those reared on  $\text{Ca}_3(\text{PO}_4)_2$ . This latter observation may be attributed to the specific odour of ammonia which may excite the larvae. It is evident from fig. 2 that the inhibitory salts caused different pattern of larval metabolism which can be characterized by a sharp fluctuations of metabolic rates decreasing with time. This stimulatory effect of lastly mentioned salts is more evident if we consider the fact that these salts caused 2-day extension of larval development. Singh, et al, (1976) reported a sharp decline of the metabolic rate values during the period from 7th to 22nd day of S. oryzae development which covers the larval duration. Similar pattern of metabolic rates for R. dominica was reported by Cambell and Sinha (1978) who found that the first larval instar (day 6) consumed 29.5  $\text{ul O}_2/\text{mg.hr}$ , whereas larvae (day 22) consumed only 16.85  $\text{ul O}_2/\text{mg.hr}$ . According to Baker et al, (1979) the metabolic rate of A. megatoma larvae was declined abruptly and then more gradually to mean values of 0.45  $\text{ul O}_2/\text{mg. wet weight per hr}$ , in 180-day old larvae. After 200-days a steep rise in metabolic rate in both males and females larvae was noticed. This latter increase was not correlated with similar one in fresh body weight.

#### Prepupal and pupal metabolic activity :

As seen in fig. 3 the highest metabolic rate for the prepupae was recorded with those reared on flour treated with  $\text{KH}_2\text{PO}_4$  followed by control prepupae. In general, prepupae showed very low metabolic rates in comparison to larvae. Pupal stages showed a flattened U-shaped curve of metabolic values.  $\text{KH}_2\text{PO}_4$  and  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  disturbed the metabolic rate values of the pupae in comparison to control. On the other hand, data presented in fig. 4 show clearly the stimulatory effect of the inhibitory salts on the

values of prepupal and pupal metabolic rate. Pupae of O. surinamensis individuals reared on diet treated with both  $\text{NH}_4\text{NO}_3$  and  $\text{Ca}_3(\text{PO}_4)_2$  exhibited typical U-shape metabolic curve.

The metabolic rate in larvae of O. surinamensis prior to pupation (prepupae) was low in comparison to other stored product insects, such as T. granarium 4.0 ul  $\text{O}_2$ /mg. hr (Burgess, 1960), 3.3 ul  $\text{O}_2$ /mg. hr for T. glabrum (Beck, 1971). On the other hand, O. surinamensis prepupae consumed more oxygen per mg. hr as compared with Dermestes vulpinus L., 1.3 ul  $\text{O}_2$ /mg.hr, (Slama and Hodkova, 1975) and A. megatoma 0.85 ul  $\text{O}_2$ /mg.hr, (Baker, et al, 1979). Similar pattern of metabolic rate for prepupae and pupae was reported by Singh, et al, (1976) for S. oryzae. According to Cambell and Sinha (1978) prepupae and pupae of C. ferrugineus and R. dominica had a lower respiration rate (calculated per mean dry weight) than did developing larvae. Baker, et al, (1979) presented a flattened U-shaped curve of metabolic rates during the pupal stage of A. megatoma.

#### Adult metabolic activity :

It is evident from fig. 5 that the metabolic rate of O. surinamensis adults differed between sexes and within each sex according to the age of the adult. Females consumed more oxygen per mg of fresh body weight than males at two different ages. Old adults, 3 - 4 week, consumed also more oxygen per unit of body weight in comparison to young ones, 0 - 1 week old.

Tricalcium phosphate raised evidently the metabolic rates of newly emerged adults 0 - 1 week old. Also  $\text{KH}_2\text{PO}_4$  raised these rates slightly, while both ammonium salts,  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  and  $\text{NH}_4\text{NO}_3$  lowered these rates.

It is evident from metabolic activity data of the newly emerged adults that the selected inorganic salts showed the same pattern of effect on both sexes.

On the other hand, mineral salts slightly raised the  $\text{O}_2$  consumption per mg. of fresh body weight in 3-4 week old males. The strongest effect was recorded with  $\text{KH}_2\text{PO}_4$ . An inverse effect was, however, seen with females. All tested mineral salts inhibited the metabolic activity of this sex at 3 - 4 week of age, in comparison to control.

It can be concluded from the above mentioned results and the literature, that O. surinamensis adults consume relatively more  $\text{O}_2$ /mg than larvae in comparison to T. castaneum (Klekowski, et al, 1967), S. granarius (Campbell, et al, 1976), S. oryzae (Singh, et al, 1976) and both C. ferrugineus and R. dominica (Campbell and Sinha, 1978). This phenomenon can be attributed to the higher locomotion

activity of O. surinamensis adults in comparison to other stored product beetles.

Effect of different mineral salts on the relationship between respiration and fresh body weight:

The relationship of respiratory rate ( $\mu\text{l O}_2/\text{ind. hr}$ ) and fresh body weight ( $\mu\text{g}$ ) of an average individual plotted on log-log scale as presented in figure 6.

A linear relationship between the 2 parameters was found for all measured larvae and both sexes of adults at two different ages. Prepupae and pupae showed a lower respiration rates than developing larvae and adults.

The effect of different salts on the above mentioned relationship was calculated as the regression  $R = a \cdot W^b$ . The calculated regressions are presented in table 6.

The values of regression coefficient  $b$  (table 6) suggest that with the increase of body weight of an average individual the rate of oxygen consumption also increased but at slower, different rates for different salts. The highest value of regression coefficient was found under control condition ( $b = 1.006$ ).  $\text{KH}_2\text{PO}_4$ ,  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  and  $\text{Ca}_3(\text{PO}_4)_3$  slightly lowered  $b$  values.  $\text{NH}_4\text{NO}_3$  showed the strongest effect on the value of this coefficient.

The values of the regression coefficient  $b$  are in the range between 0.7 which indicates body surface-metabolism relationship and 1.0 which indicates body weight-metabolism relationship as given in most of the empirical data. It can be postulated from  $b$  values that oxygen metabolism of O. surinamensis is related to body weight, except for  $\text{NH}_4\text{NO}_3$ . This chemical lowers oxygen consumption in relation to body weight. Klekowski, et al, (1967) found a linear relationship between the logarithm of  $\text{O}_2$  consumption and live body weight of all larval instars except  $L_1$  for T. castaneum. The calculated regression coefficient  $b = 0.85$ . Campbell, et al, (1976) reported an exponential relationship ( $x = 0.79$ ) between dry body weight and  $\text{O}_2$  consumption for all developing S. granarius larvae. According to Singh, et al, (1976) a power relationship between respiration rate and dry body weight of S. oryzae was found for all larval instars. The calculated  $b$  value was 0.5147.

Specific metabolism:

On the other hand, mineral salts showed remarkable effect on the specific metabolism ( $\mu\text{l O}_2/\mu\text{g.hr}$ ) of O. surinamensis in different treatments (table 6). Out of the studied salts, ammonium nitrate showed the highest stimulation of the specific metabolism ( $0.041 \mu\text{l O}_2/\mu\text{g.hr}$ ), followed by tricalcium phosphate.  $\text{KH}_2\text{PO}_4$  and  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$  showed similar effect where the calculated values of the specific metabolism are almost the same.



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Table (1)

Respiratory and metabolic rates of O. surinamensis  
 (L.) throughout its postembryonic development reared  
 on whole wheat flour, measured at 30 °C ,

Stage	Age (days)		Mean weight (fresh. mg)	Mean respira- tory rate ( $\mu\text{l O}_2/\text{ind. hr}$ ) $\pm$ S.D.	Mean metabolic rate( $\mu\text{l O}_2/\text{mg. hr}$ ) (calculated from R/W)
Larvae	6	2	0.026	0.263 $\pm$ 0.074	10.115
	8	4	0.040	0.324 $\pm$ 0.079	8.100
	10	6	0.091	2.478 $\pm$ 0.700	27.231
	12	8	0.148	3.622 $\pm$ 0.882	24.473
	14	10	0.196	4.736 $\pm$ 1.072	24.163
	16	12	0.336	6.068 $\pm$ 1.241	18.059
	18	14	0.563	2.957 $\pm$ 0.677	5.252
Prepupae	19	1	0.451	0.997 $\pm$ 0.127	2.211
Pupae	20	1	0.428	0.878 $\pm$ 0.178	2.051
	21	2	0.404	0.647 $\pm$ 0.129	1.602
	22	3	0.397	0.515 $\pm$ 0.103	1.297
	23	4	0.372	0.475 $\pm$ 0.100	1.277
	24	5	0.357	0.670 $\pm$ 0.162	1.877
	25	6	0.342	0.655 $\pm$ 0.063	1.915
Adult	25-32	0-7	0.310	2.389 $\pm$ 0.640	7.707
	25-32	0-7	0.360	3.512 $\pm$ 1.028	9.756
	46-53	21-28	0.370	4.486 $\pm$ 1.258	12.059
	46-53	21-28	0.397	10.453 $\pm$ 1.401	16.330

Table (2)

Respiratory and metabolic rates of *O. surinamensis* (L.) throughout its postembryonic development reared on (1 % conc.)  $\text{KH}_2\text{PO}_4$  measured at 30 °C.

Stage	Age (days)		Mean weight (fresh. mg)	Mean respira- tory rate ( $\mu\text{l}/\text{ind. hr.}$ $\pm$ S.D.)	Mean metabo- lic rate ( $\mu\text{l O}_2/\text{mg.hr}$ ) (calculated from R/W)
	ind.	stage			
Larvae	6	2	0.022	$0.272 \pm 0.011$	12.364
	8	4	0.046	$0.274 \pm 0.014$	5.957
	10	6	0.042	$1.042 \pm 0.395$	24.810
	12	8	0.072	$3.256 \pm 0.790$	45.222
	14	10	0.173	$4.276 \pm 1.792$	24.717
	16	12	0.270	$4.630 \pm 0.622$	17.148
	18	14	0.521	$5.053 \pm 1.360$	9.699
Prepupae	19	1	0.456	$1.195 \pm 0.288$	2.621
Pupae	20	1	0.419	$0.720 \pm 0.134$	1.718
	21	2	0.403	$0.679 \pm 0.315$	1.685
	22	3	0.366	$0.589 \pm 0.176$	1.609
	23	4	0.329	$0.445 \pm 0.096$	1.353
	24	5	0.321	$0.528 \pm 0.061$	1.645
	25	6	0.311	$0.640 \pm 0.156$	2.058
Adult	25-32	0-7	0.376	$3.379 \pm 0.976$	8.987
	25-32	0-7	0.422	$4.265 \pm 1.666$	10.107
	46-53	21-28	0.384	$6.378 \pm 0.936$	16.609
	46-53	21-28	0.428	$9.289 \pm 2.875$	21.703



Table (3)

Respiratory and metabolic rates of O. surinamensis (L.) throughout its postembryonic development reared on (1 % conc.)  $(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , measured at 30°C.

Stage	Age (days)		Mean weight (fresh. mg)	Mean respira- tory rate ( $\mu\text{l}/\text{ind. hr.}$ ) $\pm$ S.D.	Mean metabo- lic rate ( $\mu\text{l O}_2/\text{mg.hr}$ ) (calculated from R/W)
	ind.	stage			
Larvae	6	2	0.017	0.264 $\pm$ 0.011	15.529
	8	4	0.047	0.330 $\pm$ 0.161	7.021
	10	6	0.058	2.299 $\pm$ 0.396	39.638
	12	8	0.081	1.615 $\pm$ 0.395	19.938
	14	10	0.144	3.243 $\pm$ 1.092	22.521
	16	12	0.267	3.584 $\pm$ 1.347	13.423
	18	14	0.476	8.297 $\pm$ 2.614	17.431
Prepupae	19	1	0.466	0.907 $\pm$ 0.201	1.946
Pupae	20	1	0.450	0.668 $\pm$ 0.197	1.484
	21	2	0.433	0.558 $\pm$ 0.085	1.289
	22	3	0.386	0.418 $\pm$ 0.090	1.083
	23	4	0.381	0.561 $\pm$ 0.198	1.472
	24	5	0.362	0.538 $\pm$ 0.171	1.486
	25	6	0.334	0.512 $\pm$ 0.088	1.533
Adult	25-32	0-7	0.310	2.160 $\pm$ 0.645	6.968
	25-32	0-7	0.351	2.955 $\pm$ 0.586	8.419
	46-53	21-28	0.366	4.995 $\pm$ 0.852	13.648
	46-53	21-28	0.378	8.467 $\pm$ 1.690	22.399

Table (4)

Respiratory and metabolic rates of O. surinamensis (L.) throughout its postembryonic development reared on (0.5 % conc.)  $\text{NH}_4\text{NO}_3$ , measured at 30°C.

Stage	Age (days)		Mean weight (fresh. mg)	Mean respira- tory rate ( $\mu\text{l}/\text{ind. hr.}$ ) $\pm$ S.D.	Mean metabo- lic rate ( $\mu\text{l O}_2/\text{mg.hr}$ ) (calculated from R/W)
	ind.	stage			
Larvae	6	2	0.020	0.344 $\pm$ 0.013	17.200
	8	4	0.034	0.374 $\pm$ 0.013	11.000
	10	6	0.051	2.282 $\pm$ 0.519	44.745
	12	8	0.099	1.938 $\pm$ 0.415	19.576
	14	10	0.165	6.182 $\pm$ 1.225	37.467
	16	12	0.198	4.204 $\pm$ 0.805	21.232
	18	14	0.258	7.110 $\pm$ 1.573	27.558
	20	16	0.361	2.340 $\pm$ 0.665	6.482
Prepupae	21	1	0.394	1.124 $\pm$ 0.311	2.853
Pupae	22	1	0.381	0.887 $\pm$ 0.110	2.328
	23	2	0.370	0.503 $\pm$ 0.153	1.359
	24	3	0.357	0.421 $\pm$ 0.127	1.179
	25	4	0.335	0.453 $\pm$ 0.124	1.352
	26	5	0.326	0.620 $\pm$ 0.212	1.902
	27	6	0.321	0.684 $\pm$ 0.211	2.131
Adult	27-34	0-7	0.316	2.339 $\pm$ 0.914	7.402
	27-34	0-7	0.345	3.161 $\pm$ 0.843	9.162
	48-55	21-28	0.378	4.636 $\pm$ 1.268	12.265
	48-55	21-28	0.434	8.801 $\pm$ 3.020	20.279

Table (5)

Respiratory and metabolic rates of O. surinamensis (L.) throughout its postembryonic development reared on (0.5 % conc.)  $\text{Ca}_3(\text{PO}_4)_2$  measured at 30°C.

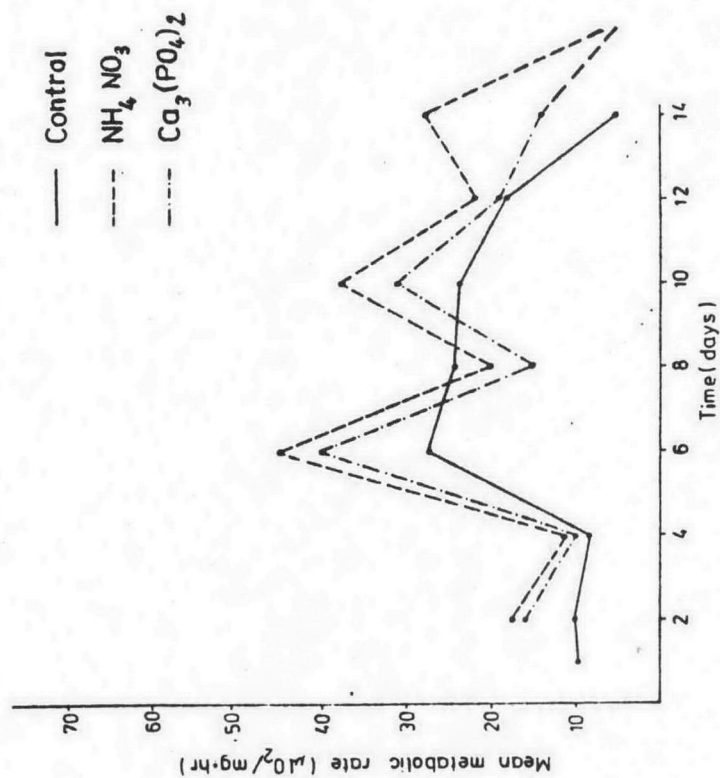
Stage	Age (days)		Mean weight (fresh. mg)	Mean respira- tory rate ( $\mu\text{l}/\text{ind.}\cdot\text{hr.}$ ) $\pm$ S.D.	Mean metabo- lic rate ( $\mu\text{l O}_2/\text{mg}\cdot\text{hr.}$ ) (calculated from R/W)
	ind.	stage			
Larvae	6	2	0.020	$0.319 \pm 0.085$	15.950
	8	4	0.030	$0.295 \pm 0.079$	9.833
	10	6	0.046	$1.867 \pm 0.449$	40.587
	12	8	0.131	$1.924 \pm 0.656$	14.687
	14	10	0.217	$6.728 \pm 0.812$	31.005
	16	12	0.308	$5.868 \pm 0.818$	19.052
	18	14	0.422	$5.905 \pm 0.736$	13.993
	20	16	0.429	$2.250 \pm 0.399$	5.245
Prepupae	21	1	0.419	$1.327 \pm 0.232$	3.167
Pupae	22	1	0.406	$0.907 \pm 0.166$	2.234
	23	2	0.392	$0.600 \pm 0.174$	1.531
	24	3	0.370	$0.480 \pm 0.127$	1.297
	25	4	0.344	$0.505 \pm 0.127$	1.468
	26	5	0.326	$0.670 \pm 0.127$	2.055
	27	6	0.319	$0.678 \pm 0.138$	2.125
	28	7	0.301	$0.818 \pm 0.121$	2.718
Adult	28-35 (0-7)		0.308	$4.103 \pm 0.515$	13.321
	28-35 (0-7)		0.317	$6.513 \pm 2.155$	20.546
	49-56 (21-28)		0.356	$4.700 \pm 1.046$	13.202
	49-56 (21-28)		0.373	$7.859 \pm 1.460$	21.070



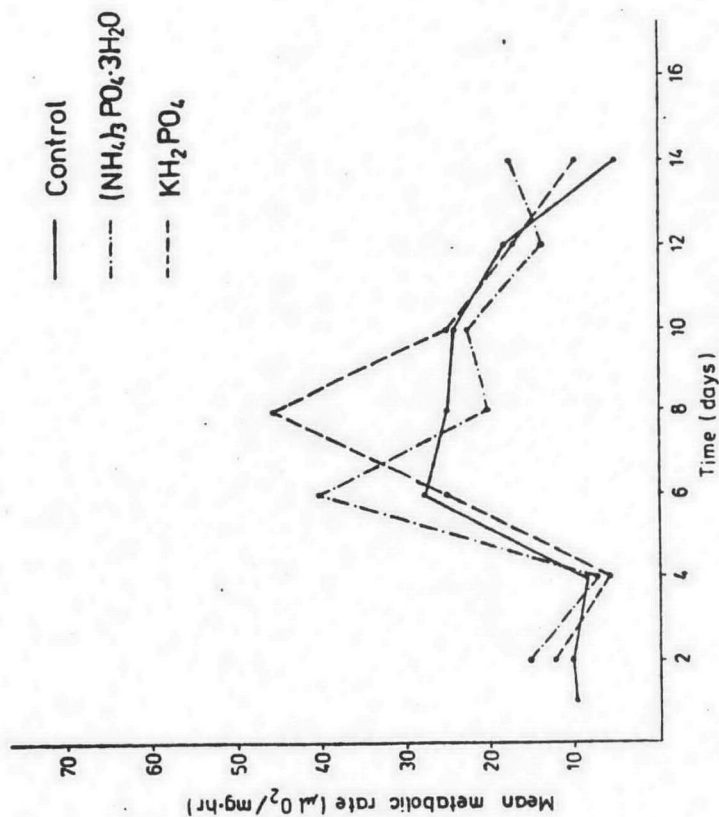
Table (6)

Effect of different mineral salts on the relationship of respiration and fresh body weight for larvae and adults of O. surinamensis (L.)

Salt	Conc. %	Regression equation	
Control		R =	$0.013 w^{1.006}$
$KH_2PO_4$	1.0	R =	$0.021 w^{0.939}$
$(NH_4)_3PO_4 \cdot 3H_2O$	1.0	R =	$0.022 w^{0.919}$
$NH_4NO_3$	0.5	R =	$0.041 w^{0.812}$
$Ca_3(PO_4)_3$	0.5	R =	$0.025 w^{0.912}$



Fig( 2 ) Effect of different inorganic salts (0.5% Conc ) on the metabolic rate of Q. surinamensis (L ) larvae.



Fig( 1 ) Effect of different inorganic salts (1% Conc.) on the metabolic rate of Q. surinamensis (L.) larvae.

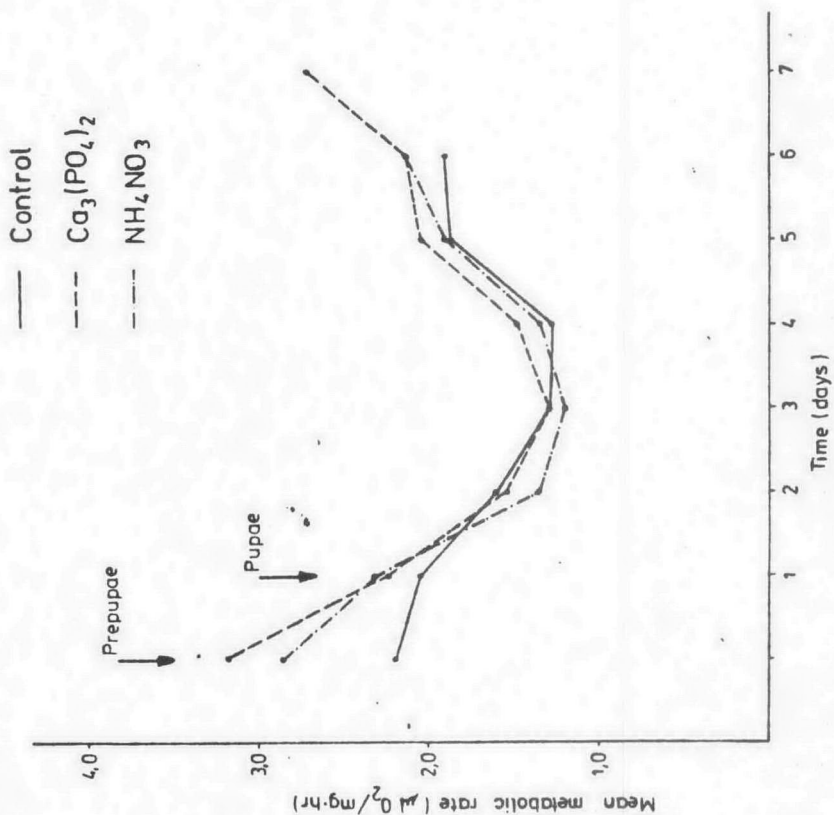
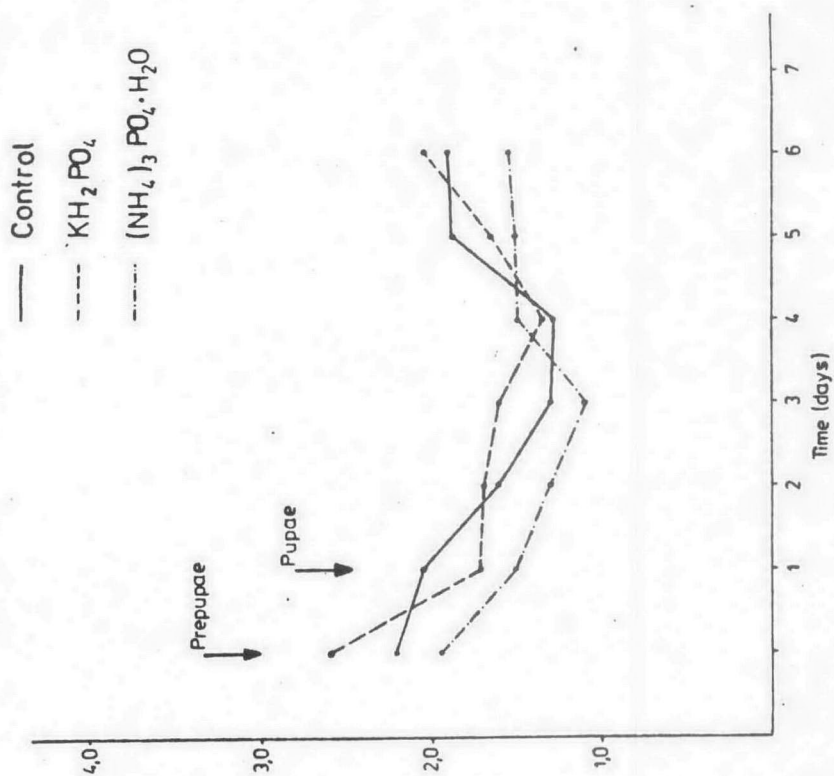
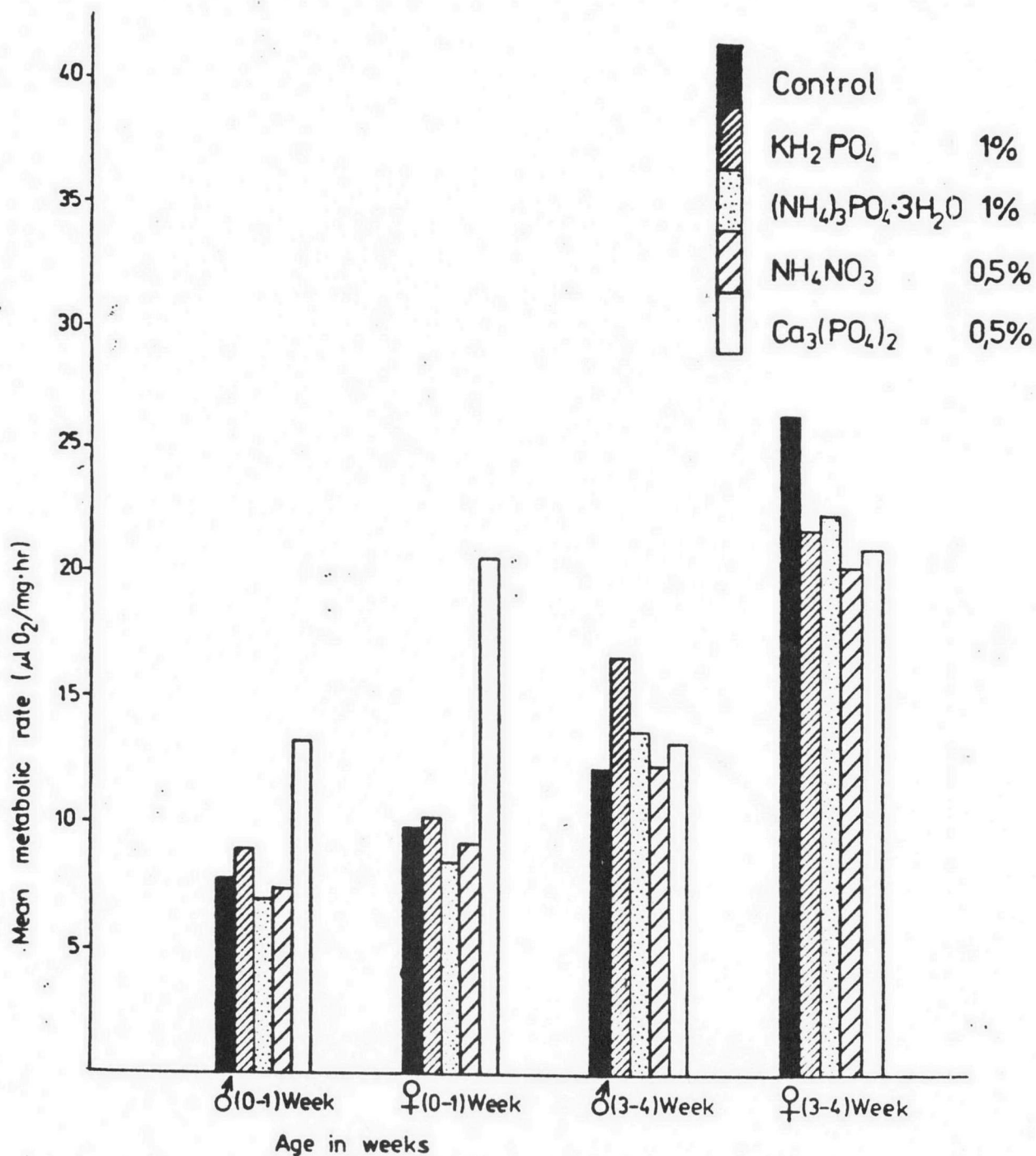


Fig ( 4 ) Effect of different inorganic salts (0.5% Conc.) on the metabolic rate of the prepupal and pupal stages of Q. surinamensis(L.).

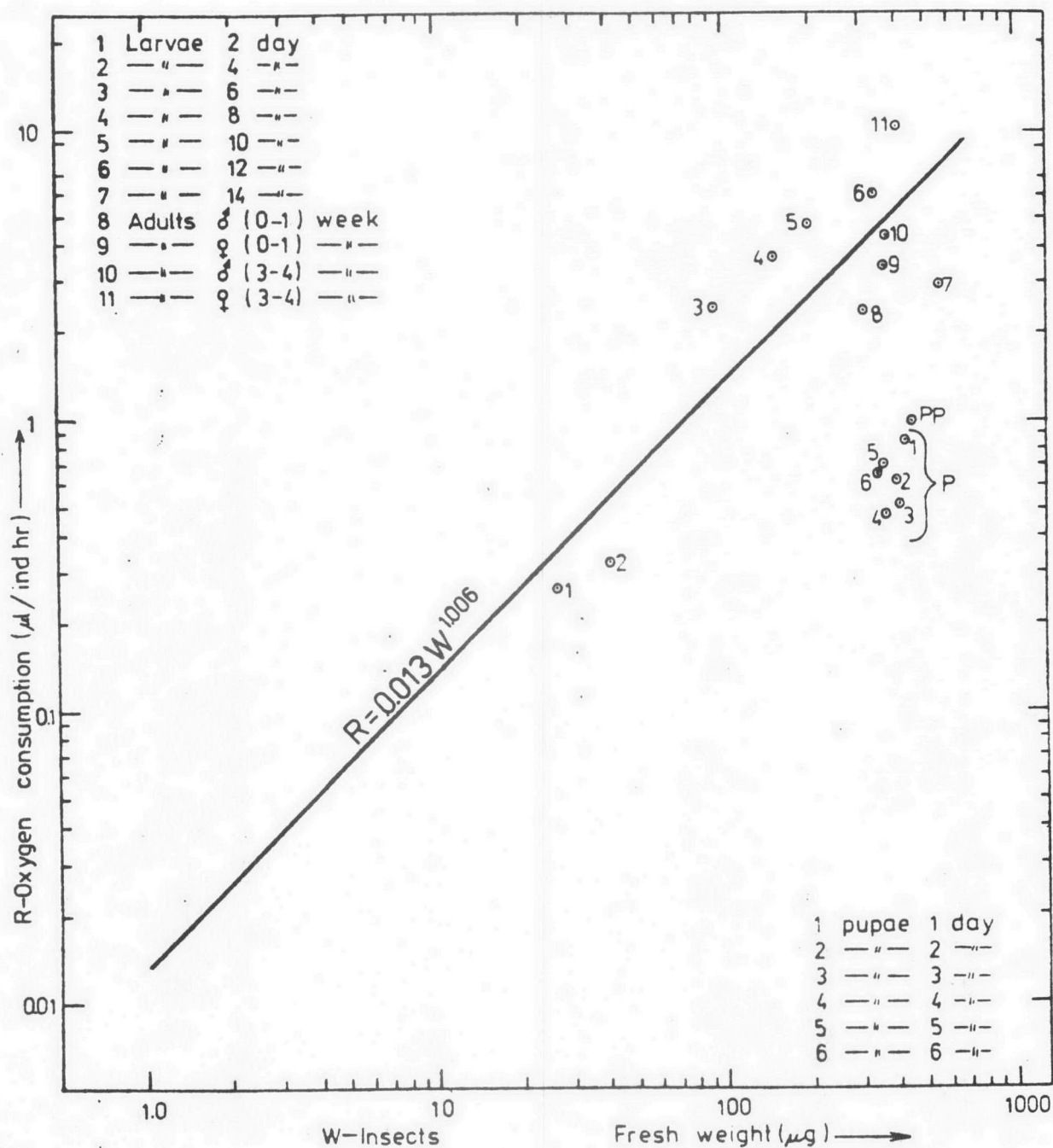


Fig(3) Effect of different inorganic salts (1% Conc.) on the metabolic rate of the prepupal and pupal stages of Q. surinamensis (L.).





Fig(5) Effect of different inorganic salts on the metabolic rate of O. surinamensis (L.) adults.



Fig(6) Weight dependence of respiratory rate of postembryonic developmental stages of *O. surinamensis* (L.) reared on whole wheat flour. Regression equation for both larvae and adults:  $R = 0.013 W^{1.006}$ .