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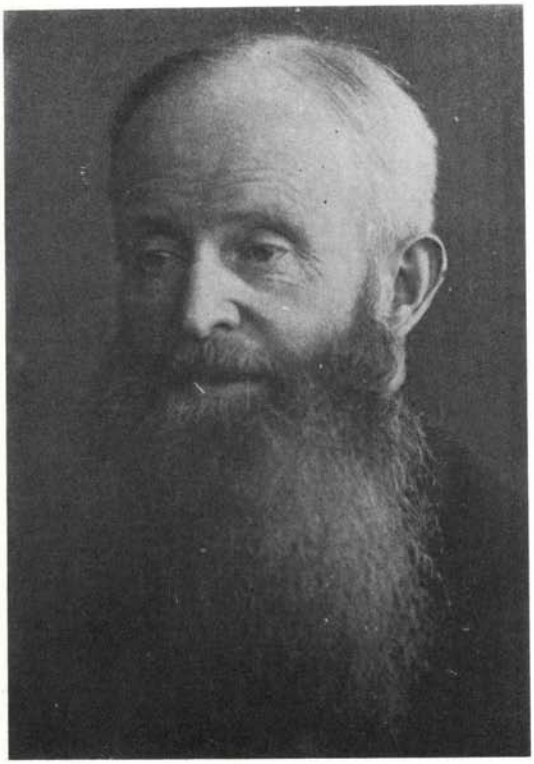

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RESPIRATION OF ANT QUEENS (Hymenoptera, Formicidae)

by
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Résumé: La respiration chez les reines des fourmis.

Par la production de reines souvent très élevée, le budget énergétique de la société des fourmis peut-etre influencé considérablement par le métabolisme de ses membres. Comme les mesures de respiration sont surtout effectuées dans des conditions artificielles, il est difficile d'appliquer leurs résultats aux nids naturels. Des mesures sur des reines sont plus complexes encore par l'effet très marqué sur la respiration de leur changements physiologiques.

Ces problèmes relatifs à la mesure de la respiration des fourmis, et en particulier des reines seront discutés. Les résultats de recherches approfondies sur les changements de composition du corps ainsi que la respiration des reines de Lasius flavus seront présentés et comparés à d'autres mesures.

Mots-clés: Formicidae, respiration, reines.

Summary: In many ant societies the production of queens is very high. Therefore the energy loss through their metabolic activity is an important factor in the energy budget for the society. For ants and other social insects respiratory measurements are often carried out under very unnatural conditions, which make the results difficult to apply to natural societies. The measurement of respiration of ant queens is even more problematic because the marked physiological changes have a great influence on the respiratory rate.

In the present paper some of the general problems connected with the measurement of ant respiration will be discussed besides some of the specific problems with ant queen respiration. The results of a detailed study of the changes in body composition and respiration of ant queens of Lasius flavus will be presented and compared with results of ant queen respiration from other investigations.

Key-words: Formicidae, respiration, queens.

INTRODUCTION

In many ant societies the production of queens is very high, and therefore the energy loss through their metabolic activity is an important factor in the energy budget. Respiratory measurements of ants are normally carried out in the laboratory under very unnatural conditions, and the findings are then applied to field conditions without too much attention to the validity of the results.

In the present paper the influence of a few factors on worker and queen ant respiration will be discussed and the results from some investigations of queen respiration will be compared with a more detailed study on Lasius flavus (F.) queens.

FACTORS EFFECTING ANT RESPIRATION

The number of factors that effect respiration can be divided into 1) the general accepted factors which act in a predictable way, and 2) factors which act in an unpredictable way, and therefore must be kept constant or investigated in each case in order to make meaningful comparison of results. The first category of factors is included in many textbooks, and it is possible to describe the effect or to compensate for these factors. The factors in the other category are by far the most difficult to handle, because they sometimes are not expected to have any influence on the respiration, and therefore often are neglected.

As social insect worker ants are used to living in close contact with other workers and the food-exchange between them is a basic part of the social organization. Queens are fed and nursed by the worker ants, and therefore the behaviour of the queens will be changed in the absence of worker ants.

The social behaviour of the ants can influence the respiratory rates. Gallé (1978) found that the group-effect (number of ants in the respiration chamber) was very strong for some ant species. For example Formica cunicularia Latr. has a specific respiratory rate of 2.55 and 1.25 μl O_2 per mg per hour with ten and one ants per respiration chamber, respectively. On the other hand Brian (1973) and Nielsen (unpubl.) found no group-effect in Myrmica rubra (L.) and Lasius flavus (F.). The number of individuals in the respiration chambers are often determined according to the sensitivity of the equipment, and therefore it might be difficult to compare results where different numbers of individuals are used.

One of the disadvantages of the social habit is that the workers have to bring most of the food back to the colony, and therefore a fairly high proportion of energy and time is used on travelling.

Worker ants are capable of great physical activity, and consequently their respiratory rate changes drastically according to their work. When ants are placed in respiration chambers they sometimes start running - in order to get out, and sometimes they remain still.

There are several external factors that might influence the motoric activity of the ants, but also the shape and size of the respiration chamber can influence the activity and therefore the respiratory rate.

Holm-Jensen et al. (1980) suggested that standard condition for metabolic studies of worker ants could be established by using anaestesia which should give a "resting" metabolism. Nielsen et al. (1982) and Jensen and Holm-Jensen (1980) measured the respiratory rate of running and of loaded worker ants and could therefore demonstrate the extra costs of running and the extra costs of carrying loads. The results showed that running worker ants increase their respiratory rate up to nine times compared to their "resting" metabolism.

Many worker ants have the ability to carry huge quantities of food as liquid in the gut when foraging. In respiratory measurements the results can be strongly influenced by this gut content, which can be up to two - three times the fresh weight of the worker. When the worker ant is resting there is no change in the respiratory rate, whereas there will be an increase in the respiratory rate due to the load carried and the distance run by the worker as it returns to the nest.

When the respiration is expressed as specific respiratory rate (respiration per unit weight) the gut content will be included in the weight of the ant. Similar problems occur when the respiratory rate of species and specimens with different content of material with low biological activities are compared.

The exosceleton is an example of a tissue with low biological activity, and its fraction of the total weight differs strongly between species. When fresh weight is used in expressing the specific respiratory rate the water content is one of the factors that might influence the results.

Accumulation of fat is a factor which can influence the weight drastically without having the same effect on the respiratory rate. The fat content in worker ant fluctuates strongly during the season, and in temperate regions most worker ants accumulate fat during the summer in preparation for hibernation. It is therefore evident that the specific respiratory rate will fluctuate during the season, whereas the absolute respiratory rate might be constant.

		Dry weight mg	Specific respiratory rate µl O_2/mg dw/h 25°C	30°C	Fat % of dw	Specific respiratory rate µl O_2/mg fat free dw/h 25°C	30°C
Lasius flavus[a]							
newly hatched	♀	2.9		2.87	22.2		3.76
two days old	♀	4.2		4.34	34.6		6.65
six days old	♀	9.8		1.24	60.1		3.06
mature	♀	9.7		1.08	60.3		2.72
Lasius flavus[b]							
young egglaying	♀	5.7		.61	44.0		1.10
	w	.5	1.97	3.14	9.1	2.17	3.56
Lasius alienus[b]							
	♀	13.6	.96		51.7	1.99	
	w	.5	2.59		40.1	4.32	
Lasius sitiens[a]							
	♀	8.7	.66		44.2	1.18	
	w	.3	1.98		32.6	2.96	
Camponotus herculeanus[a]							
	♀	52.4	.86		39.4	1.43	
	w	7.5	2.69		1.3	2.73	
Formica polyctena[c]							
newly hatched	♀		1.06				
mature	♀		.61				
winter	w	15.2	.71				
summer	w	8.6	1.08				
Pogonomyrmex montanus[d]							
	♀	6.4		3.00	36		4.72
	w	1.6		2.85	23		3.72
Pogonomyrmex subnitidus[d]							
	♀	8.1		1.93	28		2.67
	w	2.9		2.08	27		2.84
Pogonomyrmex rugosus[d]							
	♀	22.9		1.35	31		1.97
	w	5.7		1.76	14		2.04
Atta laevigata[e]							
	♀	205.1	.31				
cutters	w	4.4	2.19				
soldiers	w	16.4	1.30				
Atta rubropilosa[e]							
	♀	163.4	1.00				
	w	3.0	2.74				
	w	11.1	1.89				

Table 1. The respiratory rate of queens and worker ants.
From: a) Nielsen et al. (in press)
b) Nielsen (not published before)
c) Kneitz 1967
d) MacKay 1982, 1981
e) Beraldo and Mendes 1981

QUEEN RESPIRATION

In queens radical changes in the body composition take place in the period from emerging from the pupa until the nuptial flight and to the foundation of a new colony. Nielsen et al. (in press) have studied these changes in body composition and the respiratory rate of queens of Lasius flavus (L.). The investigations showed that during the first six days after hatching they increased their dry body weight from 2.9 to 9.8 mg, and during the same period the fat content increased from about 20% to 60% and the water content decreases from about 75% to 45%. After the nuptial flight the queens loose weight due amongst other things to the consumption of fat. As shown in Tab. 1 the respiratory rate of the queens increased strongly in the first two days and then decreased more moderately until it reached a low level for the young egglaying queen.

In the first three months of the queen's life the respiratory rate fluctuated between 3.50 and 18.40 µl O_2 per individual per hour at 30°C, and the specific respiratory rates in the same period fluctuate between 0.61 and 4.34 µl O_2 per mg dw per hour or between 1.10 and 6.65 µl O_2 per mg fat free dry weight per hour.

Table 1 shows the specific respiratory rate of queen and worker ants from different investigations carried out under different conditions. In the cases where the fat content is measured the specific respiratory rate is also expressed in terms of fat free dry weight.

In the three Pogonomyrmex-species there are no real differences between queen and worker respiration. The queens of Pogonomyrmex montanus MacKay have a higher specific respiratory rate then the workers, even though the weight is four times the worker, whereas the workers and the queens of the two other Pogonomyrmex-species have nearly the same specific respiratory rate in terms of fat free dry weight.

In Formica polyctena Förster the newly flown queen has the same specific respiratory rate as the summer worker (Kneitz 1967), whereas the heavy winter worker and the mature queen have similar but lower rates.

For the species Lasius alienus (Förster), Lasius sitiens Wilson and Camponotus herculeanus (L.) the specific respiratory rate of the queens is also lower (two to three times) than that of the workers (Nielsen, in press). All the queens in these measurements are mature queens and as the Lasius flavus (L.) investigation shows the mature queens have much smaller respiratory rates than queens in the periods just

after hatching, which may account for some of the differences in specific rates.

In the two Atta-species the great disparity in weight between queens and the other castes is associated with a much lower specific respiratory rate. Surprisingly the queens of the two species which only differ in weight by 25% show a 3-fold difference in specific respiratory rate.

As it can be seen from the different investigations of queen respiration, no clear and general conclusions can be drawn about the respiratory rate of queen and worker ants. There is no doubt that the different conditions under which the experiments have been carried out have caused at least some of the variations. It is therefore necessary to make several series of measurements where the conditions are constant before the effect of all the "special" factors can be described and a general picture of queen respiration can be shown.

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