INVESTIGATIONS INTO THE NUTRITIVE VALUE OF *MACROTERMES FALCIGER* (ISOPTERA: TERMITIDAE)

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ABSTRACT

A study was undertaken to determine the composition of the body material of alates of *Macrotermes falciger* and to investigate the nutritional value of termite material when fed to white rats. Termites were found to contain 44,3 % fat and 41,8 % protein, on a dry mass basis, and to have a calorific value of 3,2 ± 0,042 Megajoules/100 g. Incorporating termite material into commercial rat pellets at various levels produced no adverse effects on the rats. A full amino-acid analysis of termite protein is given and three unidentified amino-acids were recorded. A protein efficiency ratio of 1,7 ± 0,1 was obtained for termite protein, and digestibility of termite material was found to be poor, compared to that of casein, when fed to white rats.

INTRODUCTION

The alate form of termites is eaten by a wide variety of animals including man. However, in spite of the high level of predation large quantities of alate termites are not utilized, and it appeared that cropping of the insects at the flight season might be justified if their nutritive value were adequate. It was of interest to know what nutrients were being supplied by termites over their flight period, and how termite material ranked in comparison with other diets. It was with these considerations in mind that the current investigations were carried out.

Bodenheimer (1951) gives some data on the composition of termites, and points out that they are a source of protein food for humans in Africa, where diets are often very low in protein. The same author records that a colourless oil can be obtained from termites and it is of good quality for cooking purposes. The composition of the lipids from some termites has been dealt with by Cmelik (1969a, 1969b) and he has shown that body lipids of soldier and worker castes differ considerably from those of alates. It was also shown that the cholesterol level was very low in alates, but exceptionally high in the worker caste. Such differences indicate that the results of the current work on alates may not apply to other castes, and the cases of human fatalities after eating nearly mature nymphs of *Hodotermes*, reported by Fuller (1918), perhaps serve as a warning.

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COMPOSITION OF ALATE MATERIAL

Material and methods

The termites used in this study were alates collected in the vicinity of Salisbury, Rhodesia, and were identified by means of the keys given in Ruelle (1970) as *Macrotermes falciger* (Gerstäcker 1891) (formerly referred to as *M. goliath*). Although the sexes can be separated, this is a tedious task and, unless otherwise stated, the materials used consisted of males plus females, which occur in subequal numbers in the alate swarms.

Four batches of five termites were selected and their wings were removed and kept in separate containers to the bodies. The mass of both wings and bodies was determined and the material was then dried to constant mass in a vacuum oven at 60°C.

The fat content was determined on the same batches of termites by extraction in chloroform: methanol, 2:1, after first making a few small holes in the cuticle. The extraction was repeated until a constant mass of residual insect material was achieved after drying in a vacuum oven.

The protein content was determined by the Kjeldahl method (Pearson 1973) on three batches of the now fat-free dry material.

Separate samples of male and female termites were dried, defatted, then ground up and sent to the South African Wool Textile Research Institute for analysis by means of an amino-acid analyzer.

Glycogen was determined on four batches of ten fresh termites by the method given by Plummer (1971) using 10% trichloracetic acid for extraction, precipitating with ethanol, then determining the mass of the dried precipitate.

Calorific values were obtained for wing-free specimens. Fifteen insects of each sex were dried overnight in a vacuum oven at 70°C, then ground to a paste in a mortar. The material was split into six portions, each of about 0,4 mg, redried then burnt in a bomb calorimeter. The mass of ash residues was determined and the calorific values are expressed on an ash-free basis.

Results

Determinations of wing mass, water content, fat, glycogen, protein and cuticular residues are given in Table 1. Details of the amino-acid analysis are given in Table 2.

The calorific value for dry termite alates was 3,2 ± 0,042 Megajoules/100 g (760,5 ± 11,7 Cal/100 g) on an ash-free basis.

Discussion

Bodenheimer (1951) gives results of analyses by Tihon and also by Auffret and Tanguy. The former used lightly fried termites (of unrecorded species) obtained from a market place in equatorial Africa, and recorded 44,4% fat and 36% protein. Auffrey and Tanguy obtained 28,3% and 23,2% for fat and protein respectively in fresh termites, with corresponding values of 36,2% and 45,6% from lightly fried termites. The values obtained from the analyses of *Macrotermes falciger* (Table 1) are in reasonable agreement with these results and, from the nutritional aspect, clearly fat and protein are important. A possible source of error in the fat levels reported by Bodenheimer (1951) is that the process of frying termites may result in loss of fat, which can be seen on the exterior of insects if they are exposed to high temperatures. A further source of discrepancy between results is that fried termites frequently have legs missing, giving rise to errors when results are expressed as a percentage of mass. In the current study the insects were not exposed to temperatures over 60°C in extractive processes, and legs were included in the mass of the insects.

For comparative purposes, it is interesting to note that groundnuts (*Arachis hypogaea*) contain 23% protein and 47% fat (Platt 1945).

The calorific values for *Macrotermes falciger* are higher than the values given by Bodenheimer (1951) of 2,13 to 2,34 Megajoules/100 g (508 to 561 Cal/100 g). In the list of calorific values for insects given by Cummins and Wuycheck (1971) only one species of the Ephemeroptera approaches the calorific value of *M. falciger*. The calorific value of groundnuts given by Platt (1945) is 2,32 Megajoules/100 g (555 Cal/100 g).

Determination of protein by the Kjeldahl method may give rather inflated values with insect material, as the method is based on determination of total nitrogen, and the cuticle of insects contains nitrogen in the chitin (Wigglesworth 1972). Due to the presence of this nitrogen from a non-protein source, the results for termites shown in Table 2, in terms of grams of amino-acid per 16 g of protein nitrogen, will incorporate errors, but it was felt that the figures would serve for comparative purposes. Tryptophan is not recorded on the list of amino-acids given in

TABLE 1

Composition of alates of *Macrotermes falciger*. The masses given are mean values and standard errors for four samples of five termites each.

Component	*Mass in mg ± S.E.*	*% composition of wingless wet mass*	*% composition of wingless dry mass*
Wet mass of wings	48,0 ± 0,3	—	—
Dry mass of wings	42,1 ± 0,3	—	—
Water	696,6 ± 11,4	49,2	—
Fat	319,0 ± 2,8	22,5	44,3
Protein	300,5 ± 5,0	21,2	41,8
Glycogen	8,1 ± 0,4	0,6	1,1
Cuticle residue + ash	82,8 ± 3,0	5,9	11,5
Total wingless wet mass	1 416,4		
Total wingless dry mass	719,5		

Table 2 because this substance is destroyed by the preparative hydrolysis for analysis on an amino-acid analyzer. No further tests for tryptophan were made, but as it is of very widespread occurrence it is considered likely to be present in termites. Analysis on the amino-acid analyzer does not give accurate determinations for cystine, but the content in termites appears to be low, as is also the case in groundnuts. Methionine, the other amino-acid containing sulphur is also low relative to the rest of the amino-acids both in termites and in groundnuts. It is known that white rats have a high demand for sulphur-containing amino-acids, and that methionine is the first limiting amino-acid when groundnuts are fed to white rats (Pieterse 1963). Wessels (1967) found that methionine was also the first limiting amino-acid when groundnut meal was fed to chickens. It is possible that the termite material may be deficient in methionine and cystine, when used for nutritional purposes.

As shown in Table 2, the termite protein contained three unidentified amino-acids. One

TABLE 2

Amino acid composition of male and female alates of *Macrotermes falciger*. Values for micromoles/g are based on dry, fat-free termite material, and those for g/16gN are based on the protein content of the termite material, determined by the Kjeldahl method. Data on groundnuts are from Harvey (1956).

	Males			*Females*			*Groundnuts*	
	Micro-moles/g	*g/16gN*	*%*	*Micro-moles/g*	*g/16gN*	*%*	*g/16gN*	*%*
Lysine	343	6,4	6,6	343	6,4	6,9	3,2	3,1
Histidine	148	2,9	3,0	149	2,9	3,1	2,9	2,8
Arginine	257	5,7	5,8	275	6,1	6,5	10,0	9,8
Aspartic acid	523	8,8	9,0	494	8,3	8,9	15,1	14,8
Threonine	258	3,9	4,0	242	3,7	4,0	2,6	2,5
Serine	293	3,9	4,0	288	3,8	4,1	6,6	6,5
Glutamic acid	550	10,3	10,5	528	9,7	10,4	21,7	21,2
Proline	375	5,5	5,6	323	4,7	5,0	5,2	5,1
Glycine	461	4,4	4,5	448	4,3	4,6	5,7	5,6
Alanine	541	6,1	6,2	504	5,7	6,1	2,9	2,8
Valine	357	5,3	5,4	335	5,0	5,4	5,7	5,6
Methionine	86	1,6	1,6	76	1,4	1,5	0,8	0,8
Isoleucine	236	3,9	4,0	230	3,8	4,1	4,6	4,5
Leucine	439	7,3	7,5	417	6,9	7,4	6,6	6,5
Tyrosine	293	6,7	6,9	254	5,8	6,2	3,2	3,1
Phenylalanine	215	4,5	4,6	204	4,3	4,6	4,6	4,5
Cystine	Trace	Trace	Trace	Trace	Trace	Trace	0,9	0,9
Unidentified*	750	10,5	10,7	750	10,5	11,3	NIL	NIL

* Three unidentified amino-acids were present at a level of 200–300 micromoles each, and an estimate of their contribution to mass has been made using a molecular weight of 110 as an average for all of them.

behaved like a basic amino-acid and was eluted before lysine on the ion-exchange column. The second was eluted after phenylalanine and the third was eluted together with valine, leading to some error in the valine value given. The separation of the two compounds was good enough however, to calculate the valine values with an accuracy of 20%.

MASS GAINS IN WHITE RATS FED ON TERMITE MATERIAL

Comparisons were made between mass gains of white rats fed on rat pellets and those fed on rat pellets supplemented with 25%, 50% or 75% by mass of lightly fried alates of *Macrotermes falciger*. Diets were prepared by grinding up the dried termites and mixing with the appropriate quantity of powdered rat pellets. The mixture was then compressed into cakes 10 cm in circumference and 1 cm thick. These cakes were kept in a freezer until needed, then broken up and fed to the test animals in quantities in excess of demand. Water was freely available, and a small amount of green material was provided once a week. No detailed analysis of food intake was possible from this preliminary trial because the number of animals involved was too small. However, the trial served to demonstrate that addition of termite material to the rats' diet did not cause any detectable adverse effects. No animals were kept for a full life span so possible long-term deleterious effects were not assessed.

DETERMINATION OF PROTEIN EFFICIENCY RATIO FOR TERMITE PROTEIN

Materials and methods

A sample from a large quantity of lightly fried alates of *Macrotermes falciger* was analyzed for fat and protein, using the methods described earlier in this work. A balanced artificial diet (termed the test diet) was then made up in which termite material supplied all the protein and fat, with the overall protein content of the diet being 10%. A second balanced artificial diet (termed the basal diet) was prepared in which casein supplied all the protein, again with an overall protein content of 10%. Twenty identical cages were made with false bottoms of wire mesh so that spilled food could be collected. Suitable food and water containers were provided. Twenty 21-day-old male white rats, which had been raised on a rat pellet diet and which were subequal in mass, were selected from several litters. These animals were allocated to cages and diets at random and their masses determined just before being placed in their cages. Food and water were provided in excess of demand.

Weekly records of the masses of the animals as well as their food consumption were made for a four-week period. For each week protein efficiency ratios, calculated as

$$\frac{\text{increase in mass of test animal}}{\text{mass of protein consumed}}$$

were calculated for animals fed on either diet.

Results

The weekly mass gains, food consumption and protein efficiency ratios for the test animals are given in Table 3.

TABLE 3

Weekly mean gains in mass, mean levels of consumption of food and protein and mean protein efficiency ratios of groups of 10 male white rats fed on either the basal or test diet. All masses are in g, and standard errors of the mean are given for all values.

	Week 1		Week 2		Week 3		Week 4		Overall	
	Test	*Basal*	*Test*	*Basal*	*Test*	*Basal*	*Test*	*Basal*	*Test*	*Basal*
Mean gain in mass	8,1 ± 0,6	15,0 ± 1,8	10,3 ± 1,2	11,4 ± 1,7	11,7 ± 1,8	14,0 ± 1,1	8,8 ± 0,5	16,9 ± 1,4	38,9 ± 2,5	57,3 ± 3,0
Mean mass of food eaten	49,1 ± 2,2	52,2 ± 2,6	56,2 ± 3,1	54,3 ± 3,1	63,4 ± 3,8	63,4 ± 1,9	60,7 ± 2,3	67,5 ± 3,3	227,6 ± 9,4	237,3 ± 7,9
Mean mass of protein eaten	4,9 ± 0,2	5,2 ± 0,3	5,6 ± 0,3	5,4 ± 0,3	6,3 ± 0,4	6,3 ± 0,2	6,1 ± 0,2	6,8 ± 0,3	22,8 ± 0,94	23,7 ± 0,8
Mean protein efficiency ratio	1,7 ± 0,1	2,8 ± 0,3	1,8 ± 0,3	2,1 ± 0,3	1,8 ± 0,2	2,2 ± 0,1	1,5 ± 0,1	2,3 ± 0,2	1,7 ± 0,1	2,4 ± 0,1

Differences between the diets for the parameters measured were tested by the 't' test. In the overall comparison, the difference between diets for gain in mass was significant (P = 0,01) and between protein efficiency ratios the difference was significant at the 0,1 % level of probability. On the weekly basis, the mean gain in mass was found to differ significantly between diets in Week 1 (P = 0,05) and in Week 4 (P = 0,01). Similarly, the protein efficiency ratios were found to differ significantly between diets in Weeks 1 (P = 0,01) and 4 (P = 0,05). No other statistically significant differences were detected.

Discussion

The quantity of food eaten by rats on the test diet did not differ from that eaten by rats on the basal diet. This indicates that the termite diet was as palatable as the casein diet, and the failure of rats to gain as much mass on the test diet as they did on the basal diet (Weeks 1 and 4) was not due to low food intake.

Some generally used values for protein efficiency ratio are 3,5 for fish, 2,5 for casein, 1,7 for groundnuts, 1,5 for wheat and 1,1 for maize. The value obtained here for termite protein indicates that it is in the lower part of the range. Examining the results on a weekly basis (Table 3) shows that the protein efficiency ratios are consistently lower on the test diet, although it is only in Weeks 1 and 4 that the differences attain the level of statistical significance. This lack of significance on some occasions is probably due to the samples of rats being rather small. As the quantity of food consumed was the same for the two diets, it appears that the difference in protein efficiency ratio may be attributed to a lower digestibility of the termite proteins, and a series of experiments was carried out to test this possibility.

ASSESSMENT OF THE DIGESTIBILITY OF TERMITE PROTEIN

Materials and methods

A sample from a large quantity of lightly fried termites, which had the fat extracted by means of petroleum ether, was analyzed for protein content by the Kjeldahl method. On the basis of this protein content, balanced artificial diets were made up, as in the previous trial, to give test diets containing 10%, 15% and 20% termite protein, and a basal diet was prepared in which the protein (15%) was supplied by casein. Male white rats of approximately equal masses and 25 days old were used and were allocated at random to cages and diets, with five test animals per diet. The cages were fitted with false floors and the trays beneath these were lined with blotting paper so that dry faeces could be recovered. Suitable food and water containers were supplied. Initially, all the animals were fed with test diet, in excess of requirements, for seven days, and the food intake was measured daily. It was hoped that this period would enable the rats to become adapted to the test diet. For the five-day test period which followed the period of adjustment to diet, food was supplied to a level just below the mean maximum daily consumption for the preceding seven days. It was hoped that this would minimize variation in food intake during the test period, and so the faecal production would be better correlated with food intake. Daily records were kept of the amount of food eaten and the faecal material voided. Two samples from the entire five day faecal production from each animal were analyzed for protein content by the Kjeldahl method. The mean of these two values was used to estimate the protein content of the five day production of faeces for each animal. Digestibility of the protein was estimated as the difference between protein consumed and that voided, expressed as a percentage of the protein intake.

Results

The levels of protein intake and absorption by the rats fed on various diets are given in Table 4.

TABLE 4

Mean level of protein intake, excretion and protein digestibility by groups of five rats fed on various diets for five days. All masses are in g and the figures are mean values for the five rats ± the standard error of the mean.

Protein in diet	*Mass of food eaten*	*Mass of protein eaten*	*Mass of protein excreted*	*Mass of protein absorbed*	*Digestibility*
15% casein	46,7 ± 5,0	7,0 ± 0,8	1,1 ± 0,1	5,9 ± 0,6	84,2 ± 0,5
10% termite	30,1 ± 1,5	3,0 ± 0,2	1,6 ± 0,1	1,4 ± 0,3	45,3 ± 7,0
15% termite	29,9 ± 1,9	4,5 ± 0,3	2,2 ± 0,1	2,3 ± 0,3	50,7 ± 3,9
20% termite	33,5 ± 5,8	6,7 ± 1,2	3,8 ± 0,4	2,9 ± 0,9	40,5 ± 4,6

Discussion

The difference in food intake shown in Table 4 do not attain statistical significance when tested by the 't' test. The number of rats per treatment was low, and examination of the raw data showed that the high standard errors of the mean in the values given for the 15% casein and 20% termite diets were largely due to poor intake by one of the five rats in each case. If the trial were to be repeated with larger numbers of animals, the consumption of the casein diet might well be shown to be significantly higher than that of the termite diets. This might appear to be in conflict with the results of the previous trial, where no difference in consumption was found between casein and termite diets. However, the previous trial was carried out on termite material which had not had the fat extracted, as had been done in the present trial. It could be that termite fat increases the palatability of the termite diet.

A difficulty arises in assessing digestibility in that no estimate was obtained for nitrogen produced in the rat in the form of enzymes and abraded cells of the gut lining, and voided in the faeces. In this trial the assumption has been made that the quantity of enzymes produced in the gut is proportional to the mass of food eaten, and if this assumption is correct the digestibility figures, best referred to as apparent digestibility, are still a valid means of comparison between diets. The figures for digestibility given in Table 4 have been tested by 't' tests between diets, and the 15% casein diet was significantly higher in digestibility than any of the termite diets (the level of probability for significance being 0,01 or higher in all cases). No statistically significant differences in digestibility were detected between the three termite protein diets. The digestibility figures for the termite diets show much higher variability than that of the casein diet (Table 4). It is possible that the seven-day feeding period, using a test diet, prior to the recording period was not long enough for the rats to become accustomed to the termite diet, and better uniformity in digestibility may be obtained if this pre-test period were extended. However, examination of the raw data showed that even the best individual rat results from termite diets did not approach the worst individual result on the casein diet, and the restricted ability of white rats to digest termite protein appears to be established.

CONCLUSIONS

Macrotermes falciger contains high levels of fat and protein. The protein has an amino-acid composition that indicates a possible deficiency in the sulphur-containing amino-acids cystine and methionine. The protein has a protein efficiency ratio in the lower part of the range, similar to that of groundnuts. The digestibility of termite protein is poor, relative to that of casein, when fed to white rats. The reason for this is not clear, and it may be that termites would be more efficiently used as a protein source if fed to animals which normally take a large proportion of insects in their diet.

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