ALTERATIONS IN HOST METABOLISM BY THE SPECIFIC AND ANORECTIC EFFECTS OF THE CATTLE TICK (*BOOPHILUS MICROPLUS*)

I. FOOD INTAKE AND BODY WEIGHT GROWTH

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Abstract

This experiment was designed to measure the effects of infestation by *B. microplus* on cattle and to separate the effects of reduced food intake ("anorectic effect") from those due to the remaining factors of tick infestation ("specific effect"). Hereford cattle kept on a high-quality diet were studied over a treatment period of 11 weeks with the tick-infested animals being infested regularly with equal larval doses for each animal.

The anorectic effect accounted for approximately 65% of the depression of body weight due to tick infestation. Body weights were not related to the numbers of maturing female ticks counted on the infested animals. However, the body weights were related to food intake, the large variation in which was considered a reflection of the variable effect of the toxic principle of the tick on the appetite of the cattle.

After treatment, tick-infested cattle were kept clear of tick and run with the two control groups of cattle. Pasture was supplemented with extra rations. The compensatory gain made by the infested group was less than that of the group which had been matched with it for food intake and kept tick-free. This indicates a severe effect on the metabolism of the tick-infested animals, with prolonged after-effects.

I. INTRODUCTION

Cattle tick (*Boophilus microplus* Canestrini) has been an important problem to the cattle industry in Northern Australia since soon after its original introduction in 1872. Losses from tick fever due to infection with the protozoa *Babesia argentina* and *B. bigemina* were considerable in the early years but with the development of resistance in the tick-infested areas and the use of vaccines, losses have been much less serious (Seddon 1968). However, annual economic losses in beef production due to ticks are large (Commonwealth Bureau of Agricultural Economics 1959) as also is the cost of control measures. The spread of cattle with *Bos indicus* blood, which in terms of the numbers of female ticks reaching maturity are more resistant than British cattle, may have decreased the annual economic loss in recent years. Although some work has been done on the scientific assessment of the loss of production in the field (Norman 1957; Francis 1960; Little 1963; Johnston and Haydock 1969), there seemed to be a need to study the problem under more carefully controlled nutritional conditions.

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Results of an experiment of O'Kelly and Seifert (1970), in which two groups of yarded Shorthorn × Hereford cattle were fed on lucerne hay *ad libitum*, one tick-infested and the other tick-free, suggested that the observed difference in growth rate may have been partly due to a reduction in food intake of the tick-infested cattle. Therefore an experiment was designed to test this hypothesis and to provide suitable material to study other factors involved in the mechanics of the reduction in growth rate due to tick infestation. These other factors will be described in subsequent parts of this series.

II. Materials and Methods

Thirty grade Hereford steers, aged approximately 8 months, were brought from a property near Duaringa, 75 km west of Rockhampton, on to the CSIRO National Cattle Breeding Station, Rockhampton, in January 1968. They were ranked according to the mean of three weights taken over 10 days to March 1, 1968, and after omission of the top two and bottom four animals each successive three animals were allocated at random to one of three groups as follows:

(1) Animals kept tick-free and fed *ad libitum* ("tick-free *ad lib.*").

(2) Animals artificially infested twice weekly with 2 g of tick larvae and fed *ad libitum* ("tick-infested *ad lib.*").

(3) Animals kept tick-free and pair-fed with the corresponding animal in group 2 ("tick-free pair-fed").

After the allocation to groups, an epidemic of ephemeral fever ("3-day sickness") passed through the property and one clinical case was noted in this herd, together with marked fluctuations in the weights of some animals. The animals only increased their weight by a mean of 10 kg between March 1 and April 29, when they were put on to the experimental diet *ad libitum*, probably because of the effects of ephemeral fever and the relatively high stocking rate at which they were grazed. After the experiment had started one animal injured its leg and the whole triplicate had to be discarded, leaving seven animals in each group.

After the animals were allocated to their groups, preliminary tick counts were done on each animal, on the 19th and 20th days after 0·5- and 1·0-g infestations of larvae (separated by 1 week). These infestations were made to provide information on initial tick resistance and to check that the allocation of animals was free of bias as far as tick resistance was concerned. During the experiment proper the animals were infested with 2-week-old larvae on Wednesdays and Saturdays, and counts were done on Mondays, Tuesdays, Thursdays, and Fridays, corresponding to the 19th and 20th day after the appropriate infestation. Counts of engorging female ticks within the size range 0·45–0·80 cm were recorded on one side of each animal and the counts were doubled as an estimate of the tick burden on that day. Ticks of this size range drop within 24 hr (Wharton and Utech 1969). Counts on the 19th and 20th day have been shown at Rockhampton to be close to the peak counts and the total for these 2 days is well correlated with the total count (Seifert, unpublished data). Average counts over the period of interest were estimated by dividing the total number of ticks counted in that period by the number of days on which counts were made.

On April 11 the animals were dipped in the acaricide Asuntol (Bayer) and drenched with the anthelmintic Nilverm (ICIANZ). They were introduced to the experimental diet on April 29. On May 2 (day 0) the initial body weight used in this paper was taken and experimental control of the animals commenced. The animals were put into small stalls for feeding for 2 hr each morning and afternoon. The diet offered was in the form of pellets (50% lucerne, 30% millet, and 20% sorghum, average crude protein content 14·9%). Weights of all animals were recorded at least three times per week. The first tick infestation was on day 1 and the experiment finished on July 19, 1968, when the final body weights were recorded (day 77) and all animals were sprayed with acaricide.

As part of an experiment to study compensatory growth and its effect on carcass composition the growth of the animals was followed after the experiment until they were slaughtered. The animals were allotted slaughter weights at random, at varying levels from each experimental group up to a maximum of approximately 400 kg. During this phase, all animals were treated alike and were allowed free access to pasture, together with cattle cube supplement every second or third day, at the rate of approximately 2 kg per head per day. The animals were dipped regularly to keep cattle tick at a low level but no counts of tick were made. Fasted weights were recorded at the commencement of this phase and on the morning of slaughter.

III. Results

Figure 1 gives the mean weights of the three groups throughout the experiment proper, together with the mean daily food intake of the tick-free *ad lib.* and tick-infested *ad lib.* groups, and the tick counts recorded on the tick-infested *ad lib.* group. Daily body weights were obtained by linear interpolation and both those and daily food intakes were smoothed for each animal by using moving five-point parabolas. It can be seen that the tick-free *ad lib.* group had the lowest mean weight at day 0, although when the groups were originally allocated the mean weights of the three groups were within 1·0 kg.

The experiment can be conveniently considered in four phases. In phase I (days 0–19) no ticks were counted as only a small number had matured by the end of that phase and there was little difference in the food intakes of the three groups. There was only a marginally reduced intake in the tick-free pair-fed group, some animals not being able to eat as much as their tick-infested pairs. In phase II (from days 20–39) the effect of the presence of ticks on food intake and growth is shown. By day 35 it was obvious that tick counts were rising rapidly, so that on day 36 a reduced infestation of 1 g of larvae was given. However, since the ticks take nearly 3 weeks to mature there was to be a large delay before this action could be effective. The counts on days 38 and 39 had increased greatly. So each animal was sprayed on the head, neck, and shoulders to reduce the tick burden, which had reached 900 per side on one animal and another had been fly-struck on the heavily tick-infested neck area.

In phase III (from days 40–63) a period of compensation is shown with reduced tick numbers from the effect of spraying and also from three lighter infestations (1 g), two of which were given before the animals were partially sprayed with acaricide. Food intake of the tick-infested animals rapidly recovered but did not reach that of the tick-free *ad lib.* group.

In phase IV (from days 64–77) there was a tendency for a further build up in tick numbers, with a count of 630 ticks per side on the worst affected animal. The mean tick count was almost as high as in phase II, but the effect on growth rate was comparatively slight. Food intake of the tick-infested *ad lib.* animals remained below that of the tick-free *ad lib.* group.

The mean body weights of the three groups at day 33 (when blood samples were taken for chemical analyses) and day 77 (at the end of the experiment), adjusted to the same initial weight, are shown in comparison I in Table 1. However, statistical testing of the differences between the three groups is complicated by the fact that the experiment resulted in the variances of the weights of the tick-infested *ad lib.* and tick-free pair-fed groups being significantly greater ($P < 0 \cdot 01$) that than of the tick-free *ad lib.* group. In order to test statistically differences between the groups two further comparisons were made (Table 1). The body weights of tick-infested *ad lib.* animals were compared with tick-free pair-fed animals at constant initial body weight and food intake (comparison II). Both covariates were significantly related to body

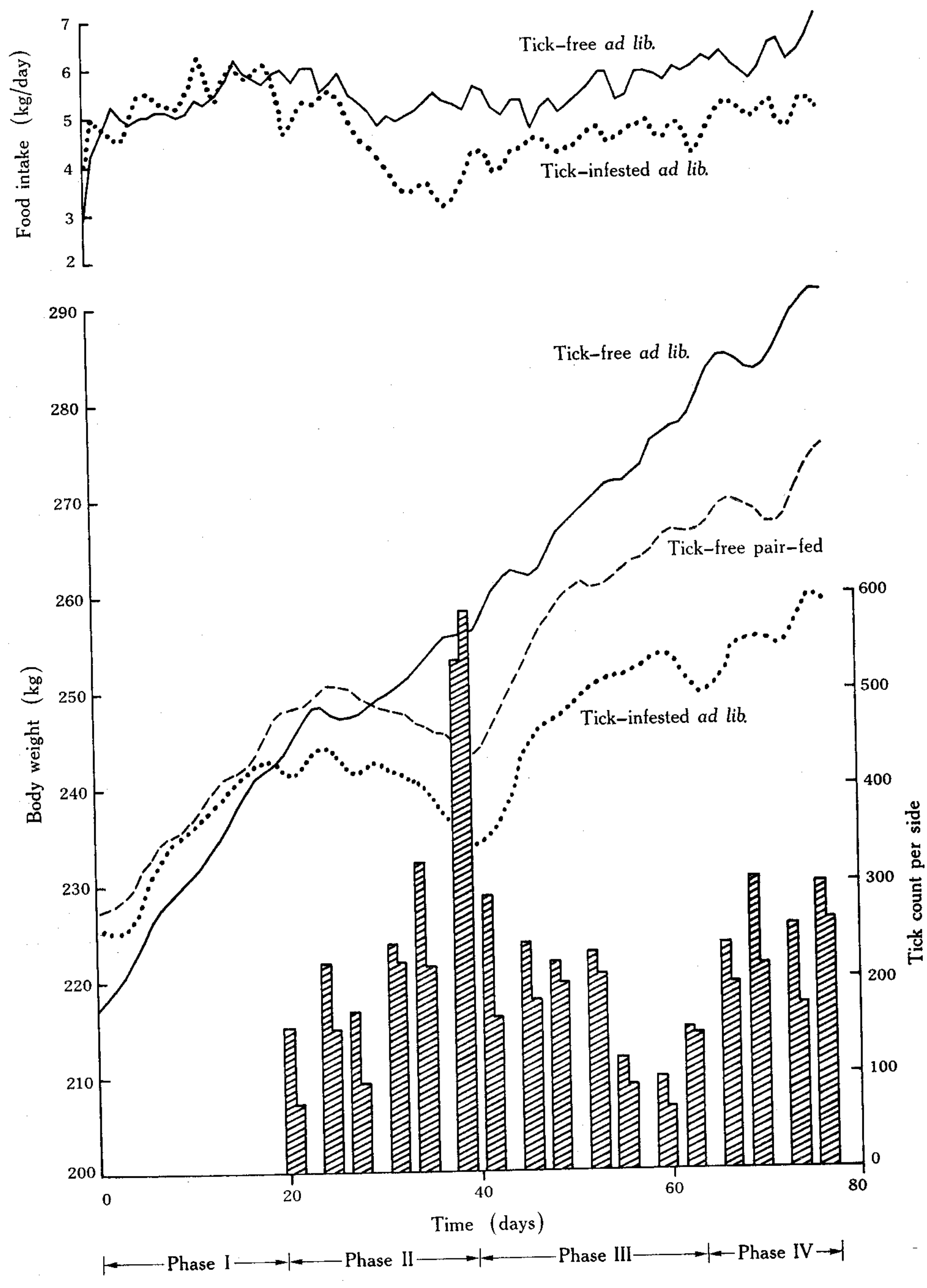

Fig. 1.—Changes in body weights, mean daily food intakes, and mean tick numbers per side in the experimental period (May 2–July 19, 1968).

weight at both days 33 and 77. The body weights of the tick-free pair-fed and the tick-free *ad lib.* groups were compared using initial body weights as a covariate (comparison III). The variances of the body weights of these two groups were still significantly different but using the approximation given by Snedecor and Cochran (1967, p. 115) to allow for this, by halving the number of degrees of freedom when testing, the two groups were shown to have significantly different ($P < 0 \cdot 01$) mean weights at day 77.

TABLE 1

COMPARISONS OF BODY WEIGHTS OF THE EXPERIMENTAL GROUPS AT DAYS 33 AND 77

Comparison	Group	Adjusted Body Weight, Day 33 (kg)	Adjusted Body Weight, Day 77 (kg)
I. Adjusted to same initial body weight†	Tick-free *ad lib.*	256·8	298·0
	Tick-free pair-fed	244·3	271·7
	Tick-infested *ad lib.*	238·1	256·6
II. Adjusted to same initial body weight and food intake‡	Tick-free pair-fed	246·2	275·7
	Tick-infested *ad lib.*	241·2	259·0*
III. Adjusted to same initial body weight§	Tick-free *ad lib.*	255·7	297·4
	Tick-free pair-fed	243·1*	269·7**

* Significant difference between groups ($P < 0 \cdot 05$).

** Significant difference between groups ($P < 0 \cdot 01$).

† Residual variances heterogeneous ($P < 0 \cdot 01$); significance tests not given.

‡ Residual variances homogeneous; normal statistical tests.

§ Residual variances heterogeneous ($P < 0 \cdot 01$); modified statistical tests (see text).

Among the seven animals of the tick-infested *ad lib.* group, there was no significant relationship between change in body weight and tick counts over the experiment. Correlations were examined for phases II, III, and IV and for the total to days 33 and 77. The animal consistently carrying least ticks had the highest growth rate but the animal worst affected in terms of growth rate carried only a low to average number of ticks.

TABLE 2

COMPARISON OF MEAN DAILY FOOD INTAKES TO DAYS 33 AND 77, ADJUSTED TO CONSTANT INITIAL BODY WEIGHT

Groups with different superscripts significantly different ($P < 0 \cdot 02$)

Groups	Food Intake to Day 33 (kg/day)	Food Intake to Day 77 (kg/day)
Tick-free *ad lib.*	5·48	$5 \cdot 66^{a}$
Tick-free pair-fed	5·16	$4 \cdot 68^{b}$
Tick-infested *ad lib.*	5·11	$4 \cdot 73^{b}$

Table 2 shows the mean food intake per animal per day up to days 33 and 77 for each group, adjusted to the same initial body weight. Using *t*-tests the daily food intake was shown to be significantly different ($P < 0 \cdot 05$) between the tick-infested *ad lib.* and tick-free *ad lib.* groups at the end of phase II but not at day 33.

Table 3 shows the post-experimental growth of the animals when all were treated alike, until slaughter at varying weights. The previously tick-free pair-fed group shows a high degree of compensatory growth. Using a paired comparison *t*-test, this is significantly more ($P < 0 \cdot 05$) than that shown by the previously tick-infested group.

TABLE 3

POST-EXPERIMENTAL GROWTH DATA FOR ANIMALS OF EACH GROUP

All animals treated alike

Experimental Group	Animal No.	Fasted Weight Day 78 (kg)	No. of Days to Slaughter	Growth Rate (kg/day)
Tick-free *ad lib.*	1	306	80	0·58
	2	291	73	0·40
	3	279	110	0·51
	4	281	45	0·40
	5	282	187	0·43
	6	244	339	0·41
	7	250	96	0·47
Mean			133	0·45
Tick-free pair-fed	1	289	10	1·27
	2	300	66	0·61
	3	278	166	0·52
	4	268	173	0·58
	5	212	124	1·13
	6	236	107	0·80
	7	253	52	0·56
Mean			100	0·78*
Tick-infested *ad lib.*	1	268	171	0·57
	2	278	17	0·51
	3	256	94	0·47
	4	259	19	0·62
	5	192	166	0·77
	6	227	215	0·55
	7	260	152	0·46
Mean			119	0·56

* Significantly greater ($P < 0 \cdot 05$) than the mean for the previously tick-infested animals, using paired comparison *t*-test.

IV. DISCUSSION

A reduction in weight gain of the tick-infested *ad lib.* group has been shown in comparison with both the tick-free *ad lib.* and the tick-free pair-fed groups. The design of the experiment was such that the contribution of reduced food intake (anorectic effect) and that of factors other than reduction in food intake (specific effect) could be separated. Thus, using comparison I in Table 1, where the three groups are compared simultaneously, the anorectic effect over the whole experiment (i.e. at day 77) can be calculated as the adjusted weight for the tick-free pair-fed group minus the adjusted weight for the tick-free *ad lib.* group (271·7 −298·0 kg = −26·3 kg). The specific effect can be calculated as the adjusted weight for the tick-infested *ad lib.* group minus the adjusted weight for the tick-free pair-fed group (256·6−271·7 kg = −15·1 kg). Thus the combined effect is −41·4 kg, and the proportion formed by the specific effect of the combined effect of tick is −15·1/−41·4 = 36·5%. At day 33 this proportion is 33·2%.

The high proportion of the effect of ticks on body weight formed by the anorectic effect in this experiment (approx. two-thirds) may not necessarily apply at lower levels of infestation. Further work is needed to define the body weight response curve to different levels of infestation and the proportion of the total effect formed by the anorectic effect. In the present experiment the level of infestation was to be maintained at the high level of 4 g of larvae per week. This was considered justified in the search for a principle and to get information for further experimentation into the mechanism of the effect of ticks, although this level is probably far in excess of most field infestations.

The index of tick resistance usually used is the number of maturing female ticks, either from a uniform infestation given to all animals or from field infestations, assuming all animals had uniform exposure to ticks. Because the correlations between tick counts and body weights were small and non-significant, the above criteria of tick resistance may not reflect the effect of tick on the animal under the conditions of this experiment. Johnston and Haydock (1969), with larger numbers of cattle and low levels of field infestation on Zebu cross and British cattle, were also unable to obtain significant within-breed correlations between tick numbers and growth rates. On the other hand, Little (1963), with low levels of infestation on British breed cattle, observed a significant correlation between tick numbers and growth rate.

In the present experiment, however, the variability in body weight of the tick-infested animals, after adjustment for differences in initial body weight, was highly related to their food intake. The residual variance of body weight at day 77 was reduced from 1053 to 113 kg^2 by using this relationship. This is partly to be expected because of the mean reduction in food intake compared with the tick-free *ad lib.* animals, but was much more pronounced than in the tick-free pair-fed animals (where the residual variance was reduced from 431 to 161 kg^2). Thus it would appear that, although the toxic effect of cattle tick was not highly correlated to the numbers of ticks infesting the animal, much of the variation in body weight growth of the infested cattle was due to the variable effect of the toxic principle of tick on the appetite of the cattle.

Subsequent to the main experiment, the compensatory growth of the animals from the tick-infested *ad lib.* group and the tick-free pair-fed group was observed when all animals were treated alike and kept tick-free. The growth rate of the previously infested animals was significantly less than that of the previously pair-fed animals. However, due to the greater depression of the weight of the infested animals, it would be expected that their subsequent rate of growth would be higher. This relative lack of compensation of the previously infested animals is indicative of a severe effect on the metabolism of these animals with prolonged after-effects.

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