

Domsiekte or Pregnancy Disease in Sheep IV.—The Effect of Obesity on the Reaction of Sheep to a Sudden Reduction in Diet.

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INTRODUCTION.

IN continuation of the work on "domsiekte" or Pregnancy Disease in Sheep (Groenewald *et al*, II, 1941) a further experiment on the effect of a sudden cut in the ration has been completed. It has been reported that if the diet of fat pregnant sheep is suddenly reduced, typical pregnancy disease is rapidly produced. Identical changes also took place in non-pregnant ewes under the same conditions but the period of semi-starvation required was very much longer. It has also been shown that in typical Pregnancy Disease there is a marked reduction in the number of circulating lymphocytes. This phenomenon, together with the production of "Pregnancy Disease" in non-pregnant ewes, appeared to warrant further study. There are numerous references in the literature (See Groenewald *et al*, I, 1941) to the rôle played by obesity or condition in the aetiology of Pregnancy Disease, it being generally agreed that heavily conditioned sheep are more susceptible. In the previous experiments the sheep were suddenly switched from an adequately balanced diet to one of poor quality veld hay. This hay was not only deficient in calorific value but also in all the important food constituents, including vitamins. It is, therefore, impossible to say whether any one food fraction is pre-eminently important in the prevention of pregnancy disease or not. In order to test out some of these points the following experiment was carried out.

EXPERIMENTAL PROCEDURE.

Nine non-pregnant, 4 to 6 tooth merino ewes were used. They were in fair condition, being taken from the available sheep on the station. At the beginning of the experiment the sheep varied in weight from 69 lb. to 84 lb. with an average of 79 lb. Their condition can be gauged from the fact that exactly similar non-pregnant ewes used in the previous experiment, when fattened up prior to starvation, averaged 103 lb. in weight.

The sheep were then divided into three equal groups as follows:—

Group 1.—To receive *ad lib.* a mixture of 90 per cent. yellow maize and 10 per cent. meat and bonemeal together with dry veld hay *ad lib.*

Group 2.—As for Group 1 but white maize substituted for yellow.

Group 3.—To receive veld hay only from the beginning.

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The sheep were fed in individual feeding boxes and were kept on these rations for 168 days, when Groups 1 and 2 were switched to dry veld hay only (semi-starvation). Blood counts and records of body weights were taken throughout the experiment.

Two other non-pregnant ewes, of the same type but which had been fattened on the same ration as given to Group 1 for some time and weighed 136 and 137 lb. respectively were also used. These also had their ration suddenly cut to dry hay only and were in addition placed in a cold room at 47° F. for 34 days when they were placed back in the camp with the others. The object of the cold room was to increase the carbohydrate metabolism and to accelerate the exhaustion of carbohydrate stored in the body. The results of this second experiment cannot be strictly compared with those of the first, as the cold treatment was only applied in one case, but it is convenient to report the results here for the sake of comparison.

RESULTS.

A. *Body Weight.*

As will be seen from Graph I, Groups 1 and 2 gained weight when put on the experimental ration but Group 1 (yellow maize) increased in weight more rapidly than Group 2 (white maize). After 133 days there was a statistically significant difference between the average weights of the two groups and this difference was maintained till the 168th day when both groups were put on to dry veld-hay only. After this change both groups lost weight equally rapidly. Group 3, which was given dry veld hay only from the beginning of the experiment (day 0 on the graph) lost weight at a rate about equal to that shown by Groups 1 and 2. This loss, however, only continued for about 20 days and then became very much more gradual. It will also be noticed that as the average weights of Groups 1 and 2 decreased, so did the rate of loss decrease.

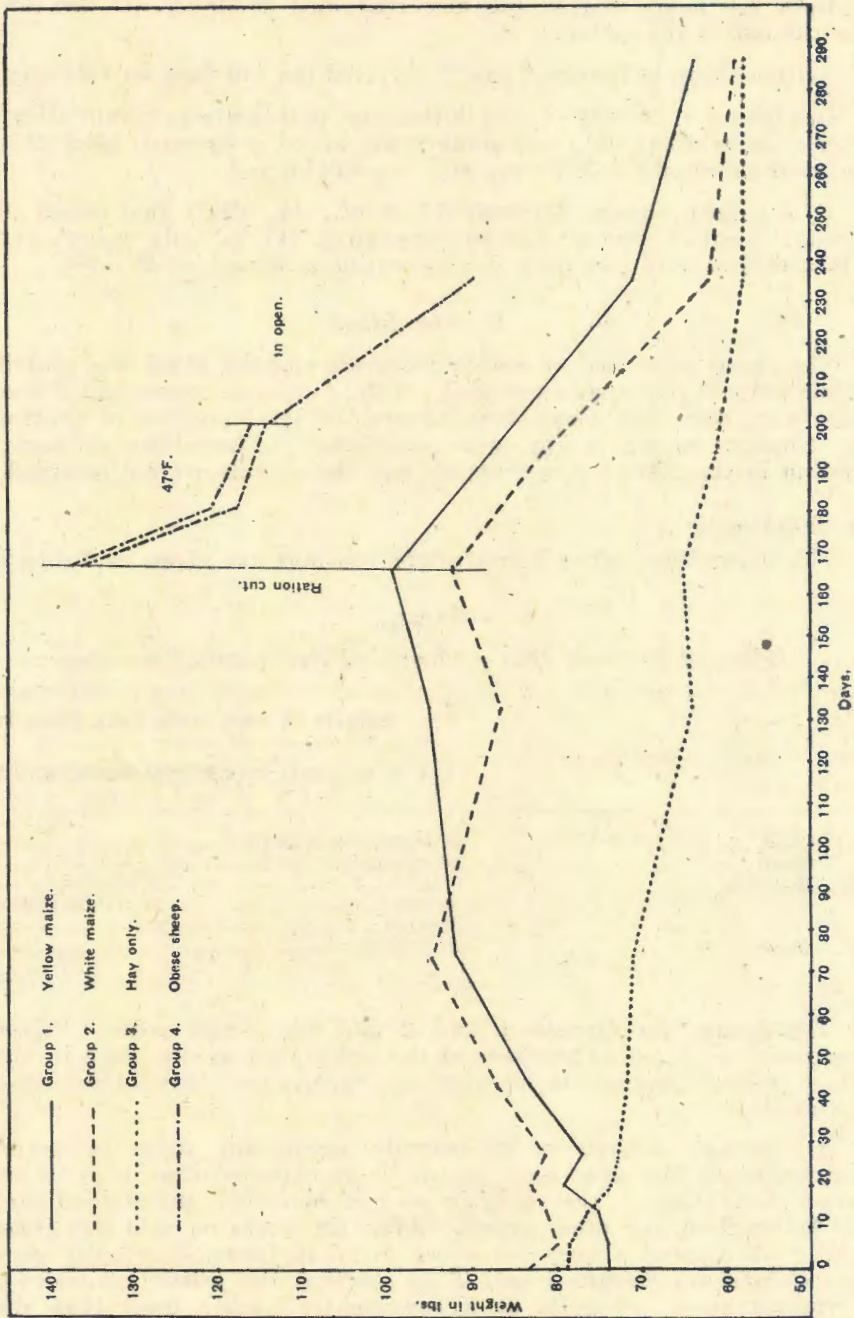
The two sheep that were placed in the cool room lost an average of 22 lb. each in the 34 days they were kept in the room. When placed back with the others but kept on the same ration the loss in weight was 23 lb. in 34 days. The temperature of 47° F., therefore, had no effect on the rate of loss of weight. The average rate of loss is shown in Table 1.

TABLE 1.

Group.	Initial Weight.	Final Weight.	Loss. (lb.).	Time. (Days).	Loss. lb./day.
Cold room.....	136	90	46	68	0.67
1.....	99	64	35	119	0.29
2.....	92	59	33	119	0.28
3.....	79	58	21	287	0.07

It will, therefore, be seen that the higher the condition of the sheep, the greater the rate of loss of weight.

GRAPH I.—Body Weight.



Reaction to Loss in Weight.

Both the heavy sheep (136 and 137) died suddenly, 59 and 69 days after the cut in the ration.

All the sheep in Groups 1 and 2 survived the 119 days on veld hay only.

One sheep in Group 3 was killed for post-mortem examination after 173 days on veld hay only and another was killed *in extremis* after 214 days. The third survived for 287 days and was discharged.

It has been shown (Groenewald *et al.*, II, 1941) that when 9 non-pregnant sheep of similar class and averaging 111 lb. body weight were put on to a diet of veld hay only, 4 died within a period of 40 days.

B. The Blood.

The sheep were bled at weekly intervals and the blood was centrifuged and the red cell precipitate recorded. Total leucocyte counts and differential counts were done and from these figures the total number of neutrophils and lymphocytes per c.mm. were calculated. There was no significant variation in the other leucocyte types and their totals are not recorded here.

The Erythrocytes.

The percentage red cell precipitate readings are given in Table 2.

TABLE 2.

Effect of Reduced Diet on Red Cell Precipitate Percentage.

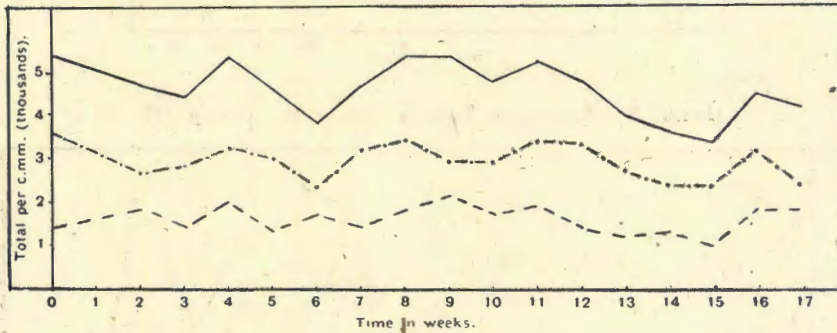
Group.	Condition.	TIME IN WEEKS AFTER DIET REDUCED.																			
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
1	Good.....	37	36	32	31	29	28	26	25												
2	Good.....	35	32	29	26	26	24	21	21												
3	Moderate.....	38	42	43									25	22	23	21					
		38	39	40									25	23	18	18	18	20	21	20	18
4	Obese.....	35	40	39									25								
		37	37	33	29																

The figures for Groups 1 and 2 and the "cold room" (Group 4) experiment are given as averages of the group, but as the sheep in Group 3 died at different periods throughout the experiment their figures are given individually.

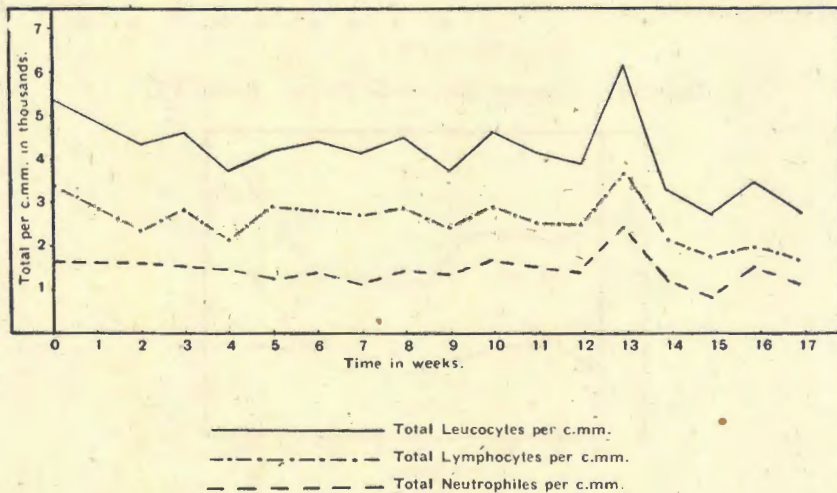
All groups showed a statistically significant drop in percentage erythrocytes on the poor diet, as would be expected, but it is of interest to note that Group 3, the sheep in poorest condition, maintained their red cells better than any other group. After six weeks on veld hay Groups 1, 2 and 4 all showed a drop but every sheep in Group 3 actually showed a rise. Comparing Groups 1 and 2 we see that the yellow maize-fed group maintained their red cells at a consistently higher level than did the white maize group (2). This is apparently to be ascribed to the reserve of vitamin A.

The figures for the leucocytes are given in Graphs II-VI. It will be seen that Groups 1, 2 and 3 all showed a drop in total circulating leucocytes during the period on poor diet. This decline is almost entirely due to a decrease in the lymphocytes, the neutrophiles maintaining their level. This drop in lymphocytes was found to be statistically significant for a combination of all groups and for Groups 2 and 3 individually, but not for Group 1. It would appear that the stored vitamin A also plays a role in maintaining the lymphocyte output. The actual drop in lymphocytes causes a relative neutrophilia, expressed as per cent., but there is no actual rise in neutrophiles.

GRAPH II.—Average Leucocyte Totals. Group I.



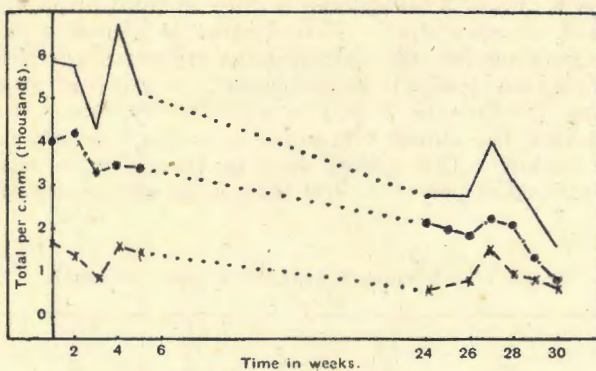
GRAPH III.—Average Leucocyte Totals. Group II.



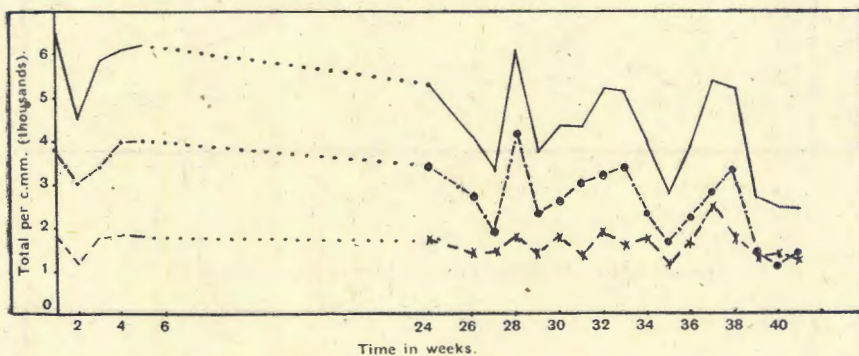
Group 4, the very obese sheep, showed an entirely different picture, namely a drop in lymphocytes and a rise in the neutrophiles, causing an inversion of the normal percentages of these elements, without the drop in leucocytes.

DOMSIEKTE OR PREGNANCY DISEASE IN SHEEP IV.

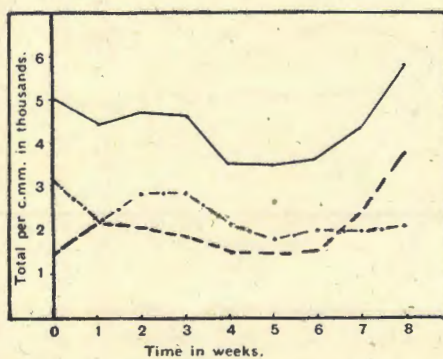
GRAPH IV.—Leucocyte Totals. Sheep A. Group III.



GRAPH V.—Leucocyte Totals. Sheep B. Group III.



GRAPH VI.—Average Leucocyte Totals. Group IV.



————— Total Leucocytes per c.mm.
 Total Lymphocytes per c.mm.
 - - - - - Total Neutrophils per c.mm.

*Post-mortem Findings.**Sheep 1. (Group 1.)*

Killed at the termination of the experiment.

Adipose tissue.—Fair amount of normal fat still present in the carcass.

Liver, kidney and myocard.—Normal.

Prescapula, Precural and Mediastinal Lymph Nodes.—Desquamation of the littoral cells of the sinuses and formation of foam cells from swollen reticulum cells in the cortex.

Sheep 3. (Group 1.)

Killed at the termination of the experiment.

Adipose tissue.—Large amount of fat still present, the abdominal fat showing fat necrosis.

Liver.—Fair amount of fatty infiltration affecting the area round the central veins.

Myocard.—Normal.

Kidney.—Well marked fatty changes of the epithelium of the spiral tubules.

Mediastinal, Mesenteric, Prescapular and Precrural Lymph Nodes.—As in Sheep 1.

Sheep 4. (Group 2.)

Killed at the termination of the experiment.

Adipose tissue.—Small amount of fat present. The internal fat shows gelatinous infiltration.

Liver, kidney and myocard.—Normal.

Mediastinal, Mesenteric, Prescapular and Precrural Lymph Nodes.—As in Sheep 1.

Sheep 6. (Group 2.)

Killed at the termination of the experiment.

Adipose tissue.—Fair amount of normal fat present.

Liver, kidney and myocard.—Normal.

Mediastinal, Prescapular, and Precrural Lymph nodes.—As in Sheep 1.

Sheep 9. (Group 3.)

Killed for examination after 173 days on dry veld hay.

Adipose tissue.—Very little fat present.

All other organs.—Normal.

Sheep 7. (Group 3.)

Killed *in extremis* after 214 days on veld hay only.

Adipose tissue.—Gelatinous degeneration of all adipose tissue.

Other organs.—All internal organs showed marked atrophy, ascites and hydrothorax present. Organs otherwise normal.

Precural and Prescapular Lymph Nodes showed mobilisation of the reticulo-endothelial system as in the other sheep.

Sheep 10. (Group 4.)

Died suddenly after 59 days on dry veld hay only.

Adipose tissue.—Large amounts of fat in all the depots showing marked fat necrosis.

Liver.—Gross fatty infiltration of the whole lobule.

Kidney.—Gross fatty changes of the spiral and proximal convoluted tubules. Well-marked desquamation of the tubular epithelium.

Myocard.—Well-marked fatty changes.

Lungs.—Oedema.

Prescapular and Precural Lymph Nodes.—Disappearance of follicles and well-marked reticulo-endothelial proliferation.

Sheep 11. (Group 4.)

Died suddenly after 69 days on dry veld hay only.

Adipose tissue.—Very large amount of fat in the depots showing fat necrosis.

Liver.—Slight central fatty infiltration.

Kidneys.—Well-marked fatty changes in the spiral tubules.

Myocard.—Fair amount of fatty changes.

Precural and Prescapular Lymph Nodes.—Follicles reduced in size and reticulo-endothelial proliferation.

DISCUSSION.

Comparing groups 1 and 2 in the initial (feeding) part of the experiment it is noted that yellow maize was superior to white maize in causing gain in weight. The yellow maize group also maintained the number of both erythrocytes and lymphocytes in the circulating blood, when put on to dry veld hay only, better than did the white maize group. These differences can probably be ascribed to the carotene content of the yellow maize.

Considering the effect of obesity on the reaction to semi-starvation groups 1 and 2 can be combined, the difference between the average weights of these groups being very small as compared with groups 3 and 4. The experiment can, therefore, be considered as follows:—

Very obese sheep.—Group 4.

Good conditioned sheep.—Groups 1 and 2.

Fair conditioned sheep.—Group 3.

All these sheep were non-pregnant ewes of similar type and age, so that the differences in weight can be ascribed to condition, chiefly to extra fat. It will be seen that the sheep reacted in very different ways to a sudden reduction in diet, according to their initial weight.

Very obese sheep.—These two sheep succumbed 59 and 69 days respectively after being put on poor diet. Prior to death they showed hypoglycaemia and acetoaemia as the following table shows.

TABLE 3.

Chemical Analysis of Blood and percentage Lymphocytes in Obese Sheep.

Time in Days.	SHEEP 10.				SHEEP 11.			
	N.P.N.	Sugar.	Acetone.	Lymphocytes.	N.P.N.	Sugar.	Acetone.	Lymphocytes.
				Per cent.				Per cent.
0	31.0	47.2	2.0	61	26.0	45.0	2.0	64
35	25.4	58.2	5.1	44	23.5	58.2	5.7	68
43	30.0	45.5	17.6	50	25.9	43.9	33.5	—
47	—	—	—	60	—	—	—	29
49	—	—	—	—	33.3	29.2	47.0	—
52	30.0	46.3	14.5	—	25.2	44.6	33.7	—
54	—	—	—	38	—	—	—	31
56	—	—	—	—	100.0	111.1	3.7	—
59	—	—	—	—	—	—	—	6
63	57.8	36.8	13.9	22	—	Died 59th day.	—	—
65	85.7	50.0	7.4	—	—	—	—	—
	Died 69th day.							

The sheep showed a typical hypoglycaemia and acetoaemia followed by a rise in N.P.N. and blood sugar and fall in acetone shortly before death. This latter phenomenon has often been encountered in the previous experiments on domsiekte (Groenewald *et al.*, 1941) and is considered to be evidence of a sudden increased catabolism of protein for the manufacture of carbohydrates. The sheep died suddenly without symptoms being noted, but the post-mortem findings were typical of pregnancy disease or domsiekte. These sheep can, therefore, be taken as further examples of typical "pregnancy disease" in obese non-pregnant ewes as previously reported (Groenewald *et al.*, 1941).

These sheep also showed the typical fall in circulating lymphocytes and rise in neutrophiles which the author has reported in all cases of typical pregnancy disease (Groenewald *et al.*, 1941). Hansheimer (1930) has shown that in acidosis of rabbits, caused by inhalation of excess CO₂ or by injection of acids, there is a similar change in the blood picture. Taking the figures for the individual sheep we find that the development of acetoaemia and the drop in percentage lymphocytes roughly correspond. This change may, therefore, be due to the acidosis.

The good conditioned sheep, groups 1 and 2, showed a rate of loss of weight intermediary between that shown between groups 4 and 3. They survived this period of rapid loss and towards the end of the period of semi-starvation their rate of loss had decreased. Out of four slaughtered at the end of 119 days on veld hay, only one showed a very slight fatty liver and

slight fat necrosis. The blood picture is also entirely different from that in pregnancy diseases, being a gradual steady decrease in lymphocytes with no change in the number of circulating neutrophiles.

The sheep in moderate condition (group 3) showed a slow loss of weight, together with the decrease in lymphocytes as seen in groups 2 and 3.

The reaction of sheep to a sudden drop in food intake, therefore, depends largely on the amount of fat present in the body. If there is an initial excess of fat the typical picture of pregnancy disease supervenes with a high acetonæmia, the sheep dying with masses of fat still present in the depôts. The less fat present, the more likelihood there is of sheep surviving the drop in weight and then surviving for a long period on a very poor diet until it eventually dies of cachexia. It is surprising that one sheep of group 3 could survive for 287 days on very poor quality dry veld grass alone. This was probably only possible owing to the fact that the sheep were free of internal parasites and that their water and food were at hand. As the veld hay used in this experiment is similar to what sheep on the highveld of South Africa have to exist on in the winter, it may be concluded that sheep can survive on this very poor feed for amazingly long periods, provided they are kept clear of internal parasites and the energy expended in seeking food and water is curtailed. Stacks of dry veld hay in close proximity to drinking water would, therefore, apparently suffice to save many sheep over our drought periods.

In 1941 Groenewald *et al* stated that, owing to the fact that typical "pregnancy disease" could be produced in non-pregnant ewes, they considered pregnancy only as a contributing factor in the causation of the disease. The present experiment shows that obesity is another potent factor. Why we do not get domsiekte on the grass lands of South Africa has long been a puzzle. The explanation may be that our grassveld sheep never attain that high condition seen in Karroo sheep.

CONCLUSIONS.

1. Obesity is a potent factor in the causation of "pregnancy disease" or domsiekte.

2. In the absence of fatal acetonæmia, prolonged semi-starvation of sheep causes a gradual decrease in the circulating lymphocytes without affecting the neutrophiles.

LITERATURE.

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