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Studies on the Alimentary Tract of the Merino Sheep in South Africa. XXIII.—The Effect of Supplementing Poor Quality Grass Hay with Molasses and Nitrogenous Salts.

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INTRODUCTION.

OVER a large portion of South Africa the basic winter diet of herbivorous animals consists mainly of poor quality grass hay which is deficient in calorific value, proteins and minerals. This results in an annual serious loss of condition in the majority of our stock and frequently also in serious losses. The economic problem is to find a practical and cheap method of supplementing such hay without using feedstuffs required for human consumption.

This question of stimulating cellulose digestion and so making greater use of the available fibrous feedstuff has received considerable attention at Onderstepoort, as shown by the publications of Louw and van der Walt (1943) and Louw, Bodenstein and Quin (1948). In the former of these investigations it was found that the supplementation of winter grazing with small amounts of meat meal or maize did not improve the digestibility of cellulose. In the latter paper the authors also report failure to improve the digestibility of cellulose by mixed supplements.

The present authors have long felt that the solution to the problem might lie in the speed of cellulose digestion and not in the percentage digestibility as shown by feed and faeces analyses.

Later Hoflund, Quin and Clark (1948) showed that the appetite of sheep for a highly fibrous diet was directly correlated to the *rate* of cellulose digestion as tested *in vitro*. They also demonstrated that both these factors could be favourably influenced by small balanced additions of sugar and protein.

It has frequently been found that sheep kept exclusively on a diet of poor quality grass hay show a gradual decrease in intake from about the third week. It is well known that the fore-stomachs of ruminants are so organised as not to allow of the passage of coarse fibrous particles into the abomasum.

It must, therefore, follow that a retardation of cellulose digestion will necessitate a more protracted sojourn of food within the rumen and a corresponding decrease in the total bulk handled in a given time.

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In view of these facts it was decided that the problem deserved further consideration. From the previous work it was obvious that in order to accelerate cellulose digestion both carbohydrate and nitrogenous compounds must be supplemented in both the correct proportion and amounts. The use of non-protein nitrogenous compounds, such as urea, has made great strides in many parts of the world in recent years and need not be discussed in detail here. It was, therefore, decided to investigate the possibility of supplementing poor quality grass hay with urea and molasses, the latter to serve as a cheap source of sugar.

Experiment 1.

In the first experiment 12 sheep were used. Each animal was placed in an individual pen with water constantly available. The food was weighed out every morning and the residue weighed back the following morning. In order to ensure that the food was available *ad lib.* the amount offered was adjusted so that the residue did not represent less than 25 per cent. of the original amount.

The sheep were divided into two groups of 6 each. Those in group 1 (controls) were fed the poor quality grass hay only. The hay fed to group 2 was treated by spraying with a solution of urea and molasses followed by rapid sun drying. For the first three weeks the treated hay contained 2 per cent. urea and 6 per cent. molasses by weight. These figures were then increased to 4 per cent. urea and 12 per cent. molasses. The animals were weighed weekly.

Results.

The results are detailed in Table 1. The daily consumption of group 2 represents pure hay, arrived at by deducting the weight of urea and molasses from the actual weight consumed.

As will be seen the sheep on untreated hay showed a gradual decline in hay consumption and a corresponding loss in body weight averaging 11·8 lb. per sheep over the trial. The sheep on the treated hay, on the other hand, maintained their intake and only lost an average of 3·1 lb. per animal.

At the end of the seventh week the control animals were in very poor condition and it was decided to place both groups on a diet of lucerne hay *ad lib.* and 300 gm. of yellow maize per day in order to ascertain whether they would gain weight equally rapidly. The object of this procedure was to test the rapidity with which a depleted ruminal flora could re-establish itself on a good diet. As will be seen both groups responded equally rapidly.

Experiment 2.

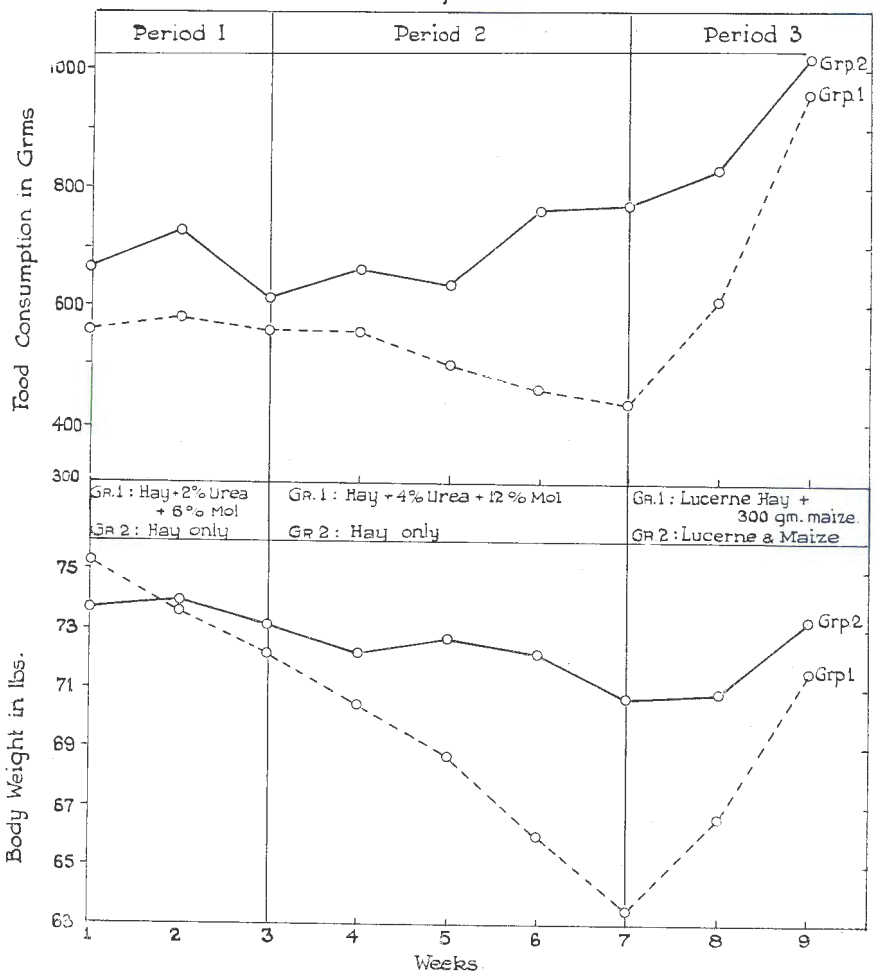
The results obtained in experiment 1 indicated that, although the feeding value and palatability of poor quality grass hay could be enhanced by the addition of urea and molasses, such a mixture did not form a satisfactory ration. This was considered possibly to be due to a lack of natural protein in the diet, which might have acted through a deficiency of certain amino-acids. It was, therefore, decided to test the effect of giving small amounts of lucerne hay to sheep on both treated and untreated grass hay.

TABLE 1.

Diet.	Gr. 1.	Untreated Hay.							Lucerne and Maize.	
	Gr. 2.	Hay plus 2 Per Cent. Urea, 6 Per Cent. Molasses.			Hay plus 2 Per Cent. Urea, 12 Per Cent. Molasses.				Lucerne and Maize.	
Weeks		1	2	3	4	5	6	7	8	9
Hay Consumption (grams)	Gr. 1	570	580	570	570	500	470	440	610	970
	Gr. 2	660	730	610	660	640	760	770	830	1,020
Body Weight (lb.)	Gr. 1	75·3	73·8	72·2	70·5	67·8	66·0	63·5	66·8	71·7
	Gr. 2.	73·8	74·0	73·1	72·2	72·7	72·2	70·7	70·8	73·3

N.B.—Figures for hay consumption represent the average daily consumption per sheep.
For convenience these figures are presented graphically in Graph I.

Graph 1



Method.

The housing and general management of the experimental animals was exactly as described for the first experiment. Sixteen merino wethers were divided into four equal groups and placed on the following rations, viz.:—

Group 1.—Grass hay only *ad lib.*

Group 2.—Grass hay *ad lib.* plus 200 gm. lucerne hay daily per sheep.

Group 3.—Grass hay treated to contain 4 per cent urea and 12 per cent. molasses by weight *ad lib.*

Group 4.—As for group 3 with the addition of 200 gm. lucerne hay per sheep per day.

Results.

TABLE 2.

Weeks.....	.....	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Hay Consumption (gm.)	Group 1	607	566	588	560	573	554	547	540	574	543
	2	560	597	615	615	647	669	691	669	724	712
	3	643	637	657	660	688	721	653	762	717	696
	4	446	470	515	557	578	615	575	631	652	650
Body Weight (lb.).	1	77·8	75·8	74·3	73·5	72·3	71·3	70·8	69·5	69·5	66·8
	2	79·0	78·0	77·8	79·0	79·8	78·5	78·5	79·8	78·5	78·5
	3	77·5	77·3	76·3	75·3	75·3	74·8	74·5	73·5	74·8	73·3
	4	77·3	76·0	76·5	77·0	77·0	76·8	76·8	75·8	76·5	75·5

These results are also given in Graph 2 in the form of free-hand trend lines for greater clarity.

It will be noted that sheep on the grass hay again showed a gradual decline in intake and a steady loss of weight.

Statistical analysis of the detailed data revealed that there was no significant difference between groups 2, 3 or 4, either as regards hay consumption or in respect of loss of body weight. All these three groups were, however, significantly different to group 1 in both respects.

This experiment, therefore, showed that the supplementation of poor quality grass hay, either with urea and molasses or with 200 gm. of lucerne hay daily, beneficially influenced not only body weight but also the intake of the grass hay.

EXPERIMENT 3.

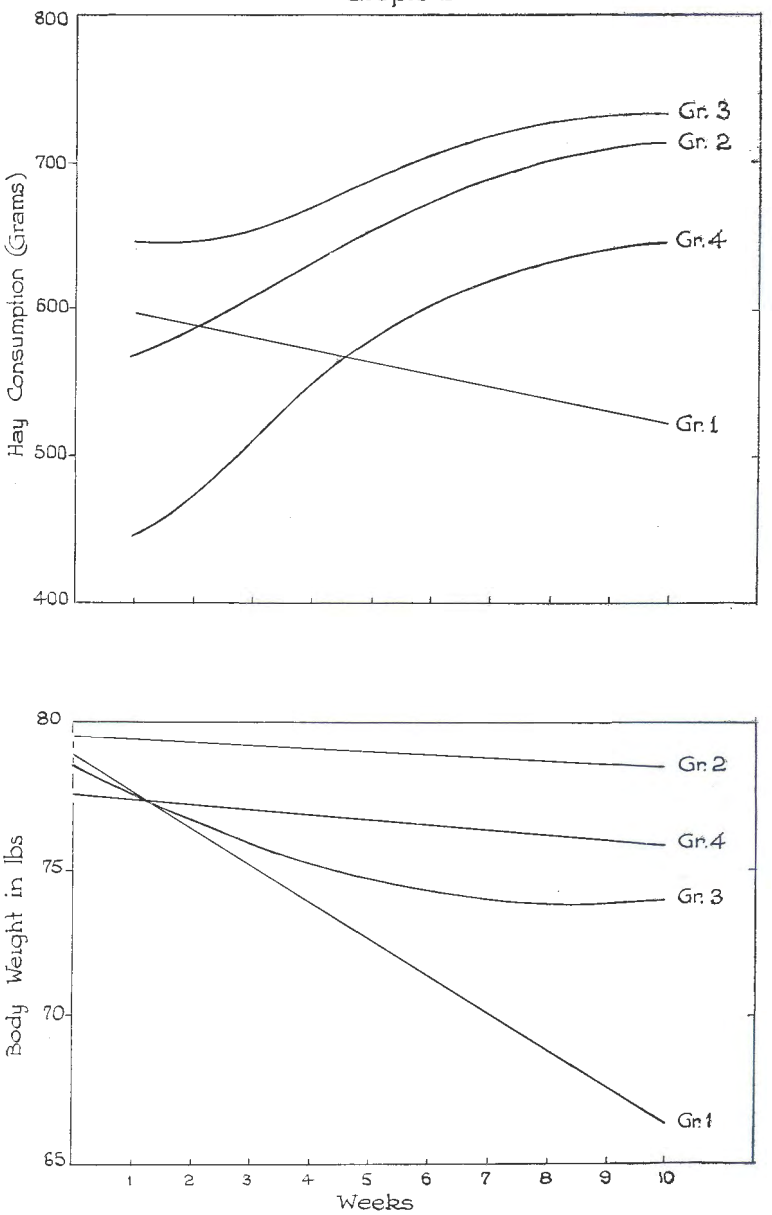
In view of the high cost of urea it was decided to investigate the use of cheaper and more readily available nitrogenous salts as possible sources of additional nitrogen. Accordingly supplies of commercial ammonium sulphate, ammonium nitrate and sodium nitrate were obtained. The nitrogen content of each was determined chemically with the following results:—

Ammonium nitrate ... ... 31·7 per cent. N.
Ammonium sulphate ... ... 20·2 per cent. N.
Sodium nitrate ... ... 15·5 per cent. N.
Urea ... ... 30·0 per cent. N.

On the previous basis of adding 4 per cent. urea to the hay, it was decided to use the above salts in the following amounts in order to keep the total nitrogen approximately constant.

Ammonium nitrate ... ... 4 per cent.
Ammonium sulphate ... ... 6 per cent.
Sodium nitrate ... ... 8 per cent.
The molases was maintained at 12 per cent. by weight.

Graph 2


800
700
600
500
400
Hay Consumption (Grams)
Gr. 3
Gr. 2
Gr. 4
Gr. 1
80
75
70
65
Body Weight in lbs
Gr. 2
Gr. 4
Gr. 3
Gr. 1
1
2
3
4
5
6
7
8
9
10
Weeks

Twenty merino wethers were used and the experiment was conducted on exactly the same lines as the two previous trials.

The animals were divided into five groups and fed as follows:—

Group 1.—Untreated hay.

Group 2.—Hay plus 12 per cent molasses.

Group 3.—Hay plus 12 per cent. molasses plus 4 per cent ammonium nitrate.

Group 4.—Hay plus 12 per cent. mollasses plus 6 per cent. ammonium sulphate.

Group 5.—Hay plus 12 per cent. molasses plus 8 per cent. sodium nitrate.

At the end of the fourth week groups 4 and 5 were doing so badly that it was decided to reduce the amounts of the salts to 4 per cent. in each case. The results are given in Table 3.

TABLE 3.

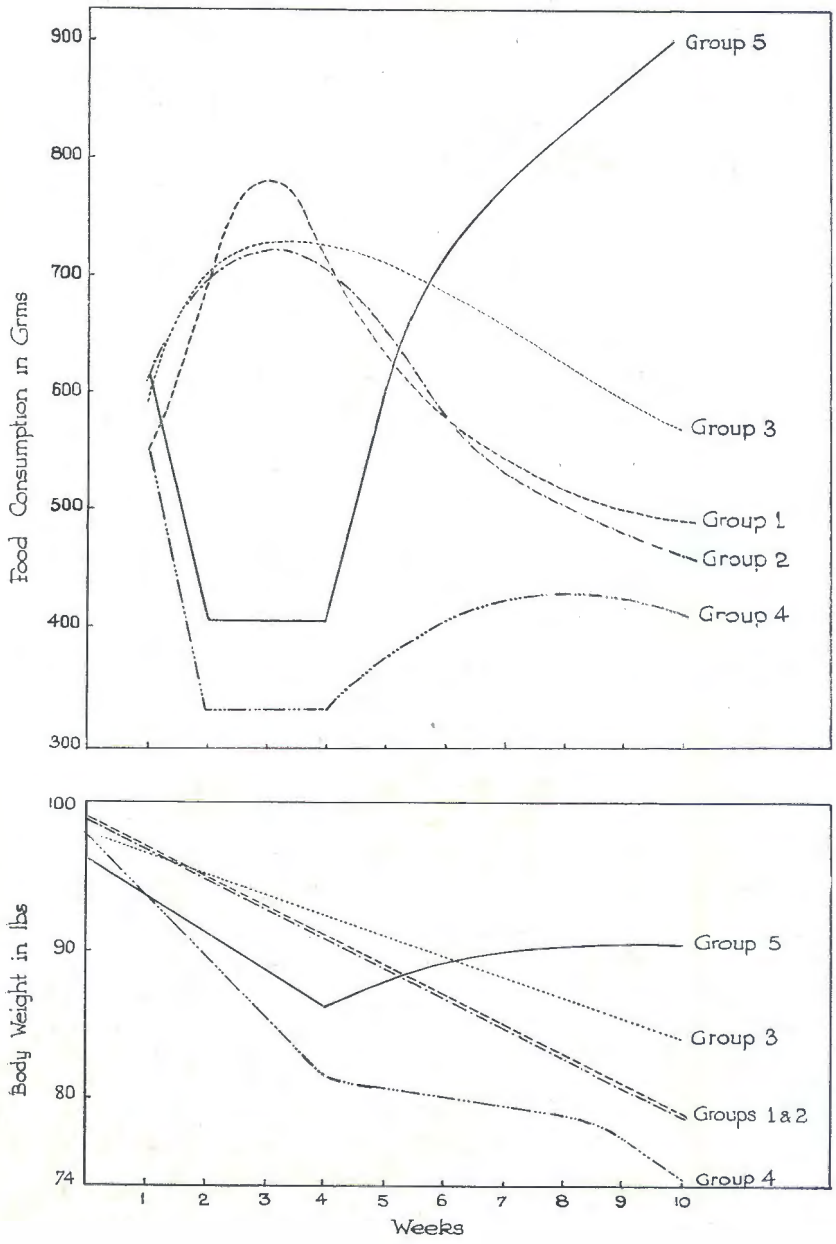
Weeks.....		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	Group.										
Hay Consumption (gm.)	1	550	680	840	680	670	550	560	540	490	500
	2	590	690	720	670	700	610	500	490	500	430
	3	590	680	720	670	690	710	680	590	580	620
	4	560	330	340	310	390	390	420	440	400	410
	5	610	410	410	410	600	720	780	790	880	890
Body Weight (lb.)	1	95	95	93	91	89	88	83	82	82	78
	2	96	95	94	92	90	87	83	81	82	78
	3	96	95	94	92	90	91	87	85	86	84
	4	96	89	86	81	81	80	80	78	78	74
	5	95	92	89	86	88	88	90	90	91	89

These results are also depicted in Graph 3.

The following facts can be noted from the above results:—

1. *Group* 1 (untreated hay) and *Group* 2 (hay plus molasses) both showed a steady loss of weight throughout the experiment. The addition of molasses only to the hay, therefore, had no demonstrable beneficial effect.
2. *Group* 3 (hay plus molasses plus ammonium nitrate) showed a slightly higher intake of hay and a slightly less rapid loss of body weight, but this feed in no way approached a maintenance ration.
3. *Group* 4 (hay plus molasses plus ammonium sulphate) showed a marked depression of appetite and rapid loss of condition during the first four weeks when they were receiving 6 per cent. ammonium sulphate on their hay. When this amount was reduced to 4 per cent. the intake improved and the rate of loss of weight decreased but the ration still proved inferior to the untreated hay.

Graph 3


900
800
700
600
500
400
300
Food Consumption in Grms
Group 5
Group 3
Group 1
Group 2
Group 4
100
90
80
74
Body Weight in lbs
Group 5
Group 3
Groups 1 & 2
Group 4
1
2
3
4
5
6
7
8
9
10
Weeks

4. *Group* 5 (hay plus molasses plus sodium nitrate). For the first four weeks, when the nitrate was added to the hay at the rate of 8 per cent., animals also showed a marked depression of appetite and rapid loss of weight. The reduction of the amount of nitrate to 4 per cent., however, resulted in an immediate increase in intake and a slow gain in weight In fact, this group was the only one which maintained their body weight during the last six weeks of the experiment.

Discussion.

The first two experiments showed that the addition of molasses and urea to poor quality grass hay definitely improved its feeding value. This was not only due to the nutritional value of the supplements themselves, but also in part to a greater use of the basic ration as indicated by the greater intake. At the end of the second experiment a digestibility trial was carried out on groups 1 and 3 (untreated hay and hay plus 4 per cent. molasses and 12 per cent. urea respectively) by Miss. S. I. Bodenstein of the Section Biochemistry and Nutrition.

The trial was carried out over ten days and the faeces were collected in bags held in place by means of a harness. The faeces were collected twice daily and sun dried. The feed was weighed out daily and a moisture determination was done. The residual food was collected for each sheep separately over the ten days when samples were taken for both moisture determination and analysis. The techniques used were as follows: Cellulose, Crampton and Maynard (1938); nitrogen, Kjeldahl, and sugars, Schaffer-Somogyi micro-method [as quoted by Browne and Zerban (1941)]. The sugars were determined as reducing sugars and expressed as glucose.

The analyses of the rations were as follows:—

	Cullulose Per Cent.	*Nitrogen Per Cent.*	*Sugar Per Cent.*
Hay	36·23	0·752	2·6
Treated hay	32·26	2·256	7·3

The results over the ten-day period are given in Table 4.

As will be seen the percentage of cellulose digested was not influenced by the presence of extra sugar and nitrogen but the total amount of cellulose digested in the ten-day period was considerably greater when the hay was treated. The average amount of cellulose digested daily by the sheep on untreated hay was 89·7 gm. as against 118 gm. digested by those on treated hay, representing an increase of 31 per cent. On this hay the factor limiting the digestibility co-efficient of cellulose would appear to be in the nature of the fibre itself and not in the presence or absence of other microbial nutriments. Lignification probably plays a major rôle in this regard. The digestion of a greater amount of cellulose in a given time can only be explained by an increased rate of digestion. This question of the rate of cellulose breakdown would appear to be of paramount importance whenever poor quality fibrous feeds form the major portion of the diet. Owing to the low nutritional quality of the ration a rapid turn-over and large intake are essential to supply the body requirements and this is only possible if cellulose digestion is accelerated.

From a practical point of view the most significant finding from experiment 2 was that the addition of as little as 200 gm. of lucerne hay daily to poor quality grass hay formed a maintenance ration for sheep under the conditions of the experiment. Here again the lucerne hay acted not only directly but also by increasing the consumption of the grass hay.

TABLE 4.

Group.		Untreated Hay.				Treated Hay.			
Sheep.		1.	2.	3.	4.	9.	10.	11.	12.
Dry Matter Digestion.....	Total Intake.....	3,576	4,195	4,375	6,531	6,024	8,443	4,846	8,501
	Amount Digested.....	1,519	1,913	1,935	2,621	2,803	3,684	2,234	3,821
	Digestibility Co-efficient...	42·5	45·6	44·2	40·2	46·5	43·6	46·1	44·9
Cellulose Digestion.....	Total Intake.....	1,286	1,497	1,491	2,309	1,981	2,704	1,579	2,729
	Amount Digested.....	704	852	799	1,231	1,063	1,364	883	1,411
	Digestibility Co-efficient....	54·7	56·9	53·6	53·3	53·7	50·4	55·9	51·7
Apparent Nitrogen Digestion.....	Total Intake.....	23·27	34·90	37·05	53·91	117·9	198·2	77·8	183·3
	Amount Digested.....	—	9·1	7·9	8·9	78·2	137·1	42·2	122·5

Referring to experiment 3 it will be noted that the addition of ammonium salts had a deleterious effect, but that the group on sodium nitrate showed an increase in cellulose consumption and decreased loss of body weight. This raises the question as to whether the presence of the ammonia radicle interferes with the normal activity of the ruminal flora, a matter which will have to receive further attention.

It would appear that nitrates can safely and advantageously be substituted for urea as a partial source of nitrogen provided sufficient sugar is given simultaneously. Sodium nitrate up to 4 per cent. and 12 percent. molasses by weight added to the hay resulted in accelerated cellulose digestion. Nitrates tend to be reduced to nitrites in the rumen resulting in methaemoglobinaemia but, as shown by Sapiro, Hoflund, Clark and Quin (1949) the accumulation of nitrite from a given dose of nitrate depends on the state of the ruminal flora and the presence of sugars. With an active flora and sufficient sugar, large amounts of nitrate produce no harmful effects. This is demonstrated by the fact that the sheep in experiment 3 ate over 30 gm. of sodium nitrate per day over a period of 3 weeks, without showing any signs of toxic effects. This remarkable tolerance can be ascribed to the simultaneous high intake of sugar.

SUMMARY.

1. In a series of three experiments it has been shown that the supplementation of poor quality grass hay with either urea or sodium nitrate, in conjunction with molasses resulted in increased appetite and improved maintenance of body weight.

2. These beneficial effects were not only due to the extra nutriments derived from the supplements but also to an acceleration of cellulose digestion allowing of a greater utilisation of the basic hay.

3. Although the rate of cellulose digestion was accelerated the percentage of cellulose digested was not influenced.

4. The feeding of 200 gm. of lucerne hay per day also increased the rate of cellulose digestion resulting in an increased consumption of grass hay.

5. Indications that the presence of ammonia radicle is deleterious to the activity of the ruminal flora will have to be studied further. The possibility of using nitrates to supplement the rations of ruminants will also have to be explored.

REFERENCES.

BROWNE, C. A. AND ZERBAN, F. W. (3rd edit. 1941). Physical and Chemical Methods of Sugar Analysis. John Wiley and Sons Inc., New York, p. 846.

CRAMPTON, E. W. AND MAYNARD, L. A. (1938). The relation of Cellulose and Lignin content to the Nutritional Value of Animal Feeds. *Jl. of Nutr.* Vol. 15. pp. 383-395.

HOFLUND, S., QUIN, J. I. AND CLARK, R. (1948). Studies on the Alimentary Tract of the Merino Sheep in South Africa. XV. The influence of different factors on the rate of Cellulose Digestion (*a*) in the rumen and (*b*) in ruminal ingesta as studied *in vitro*. *Onderstepoort Jl.*, Vol. 23, pp. 395-409.

LOUW, J. G. AND VAN DER WATH, J. G. (1943). The Influence of various Maize Supplements on the Digestibility of Cellulose in a pood Veld Hay in relation to the bacterial population of the Rumen of Sheep with a note on the Nitrogen Metabolism. *Onderstepoort Jl.*, Vol 18, pp. 177-190.

LOUW, J. G., BODENSTEIN, S. I. AND QUIN, J. I. (1948). The Digestibility, for Sheep, of the Cellulose in a poor Veld Hay, as affected by Supplements of a Mixture of Concentrates and Green Feed. *Onderstepoort Jl.*, Vol. 23, pp. 239-259.

SAPIRO, M. L., HOFLUND, S. CLARK, R. AND QUIN, J. I. (1949). Studies on the Alimentary Tract of the Merino Sheep in South Africa. XVI. The fate of Nitrate in Ruminal Ingesta as studied *in vitro*. *Onderstepoort Jl.*, Volume 22, pp. 357-372.