THE EFFECT OF THRICE-WEEKLY INGESTION OF UREA ON WOOL PRODUCTION BY GRAZING SHEEP.

By A. W. PEIRCE, D.Sc. (Principal Research Officer, Division of Biochemistry and General Nutrition, C.S.I.R.O.), G. R. MOULE, B.V.Sc. (Director of Sheep Husbandry, Queensland Department of Agriculture and Stock), and M. N. S. JACKSON, M.C. (Senior Adviser in Sheep and Wool, Queensland Department of Agriculture and Stock).

SUMMARY.

Two trials of the effect of urea on wool production of Merino sheep were conducted in north-western Queensland.

The urea was incorporated in compressed rations containing ground wheat and molasses, or ground wheat, bloodmeal and molasses, or was given as a mixture with molasses. These supplements were given thrice-weekly and, depending on the one used, the amount of urea offered on each occasion ranged from 25g. to 45g.

In general, the urea-containing rations were not palatable.

Each of the urea supplements in the amount given was toxic.

The feeding of urea did not lead to increased wool production.

I. INTRODUCTION.

The first two experiments in this series (Peirce 1951 a, b) demonstrated the ability of urea to increase the wool production of Merino sheep fed on a low-protein ration which contained an adequate amount of a readily available carbohydrate (starch). In these two experiments the urea was administered daily to sheep maintained in pens.

The investigation was then extended as a third experiment of the series to sheep grazing under natural conditions in an area in which they were subjected to a low protein intake for a considerable portion of the year. In this third experiment a cereal grain (wheat) was substituted for starch as the source of readily available carbohydrate; furthermore, in order to conform more nearly to recent recommended practices in drought feeding, and especially to reduce the amount of labour involved in carrying out the experiment, the urea was administered three times each week instead of daily.

The results of the two trials constituting this experiment and carried out as a collaborative investigation by the Queensland Department of Agriculture and Stock and the Division of Biochemistry and General Nutrition of the Commonwealth Scientific and Industrial Research Organization are given in this paper.

II. EXPERIMENTAL PROCEDURE.

The sheep selected for the experiment, comprising 130 Merino wethers (6-tooth), were transferred to the experimental site in November 1951, and were allowed to graze undisturbed until the following May. The first trial began at the end of June 1952, and concluded at the end of March 1953. The second trial commenced at the beginning of August 1953, and concluded at the end of January 1954.

(1) Location of Experiment.

The experiment was carried out on the Toorak Field Station of the Queensland Department of Agriculture and Stock situated near Julia Creek, about 1,000 miles north-west of Brisbane. Of the mean annual rainfall of 15 inches, about 90 per cent. falls between December and March. The rainfall is very variable and rather unreliable. The principal pasture species are Mitchell grasses (species of *Astrebla*), with bull Mitchell (*A. squarrosa*) the dominant species. These grasses are long-lived perennials, forming dense tussocks, which grow rapidly after the heavy summer rains but soon reach maturity and dry off. However, they remain palatable unless spoilt by winter rains, which are usually not sufficient to bring about fresh growth. A number of weakly perennial, facultatively perennial and annual forms also make good growth with the summer rains and may provide a substantial contribution to the grazing for a brief period. Among the most important of these are the Flinders grasses (species of *Iseilema*).

(2) The Diets.

All the sheep grazed together on the available pasture throughout the experiment but were brought into the sheepyards on Monday, Wednesday, and Friday of each week. After being separated into their various groups, they were placed in individual stalls and were offered the appropriate amounts of their various supplements in aluminium basins.

In the first trial, when there were five groups, designated A, B, C, D, and E, four different supplementary rations were offered. The composition and daily allowance of these are given in Table 1.

Table 1.

COMPOSITION OF SUPPLEMENTS AND AMOUNTS REQUIRED, FIRST TRIAL.

Material.	Group B : Low-protein.	Group C : High-protein.	Group D : Urea.	Group E : Molasses + Urea.
	%	%	%	%
Ground Wheat	90	36	80	..
Molasses	10	8	8	86·5
Casein	..	56	..	..
Urea	..	..	12	13·5
Supplement daily (g) ..	113·5 (4 oz.)	99·5 ($3\frac{1}{2}$ oz.)	127·5 ($4\frac{1}{2}$ oz.)	141·5 (5 oz.)
Supplement thrice weekly (g)	265	232	298	330

The materials of the supplements for groups B, C, and D were mixed and compressed into "nuts," but for group E, urea was dissolved in water and mixed with the molasses and the added water removed by boiling under vacuum. However, this last mixture was diluted with water before use and was then administered as a drench. Each of the supplements provided approximately 320 "useful" Calories per day. The supplements for group B provided approximately 2 g. nitrogen per day and those for the remaining groups provided approximately 9 g. nitrogen per day. The urea provided approximately 80 per cent. of the nitrogen of the supplement for group D and almost 100 per cent. of that for group E. The sheep of groups D and E were offered approximately 36 g. and 45 g. urea, respectively, on each of the three days of the week. Feeding of the supplements to groups B, C, and D was commenced at the beginning of the trial but that to group E did not begin until the twelfth week.

Severe drought conditions were prevailing in the area at the time the trial began, as the rains in the previous summer had been too light to bring about growth of the pastures. The small amount of grass which remained was harsh and blackened and was unpalatable to the under-nourished sheep, and it became evident that additional supplements would be necessary. Consequently, in the fourth week the feeding of a ration of maize to all sheep, including those of group A (control group), was commenced; the amount offered was 8 oz. per head thrice weekly, equivalent to approximately $3\frac{1}{2}$ oz. per day.

A salt mixture consisting of sodium chloride 25, calcium carbonate 20, magnesium sulphate 15, potassium chloride 5, monocalcic phosphate 15, and sodium sulphate 20 parts was offered to all sheep from the fifth week, the amount being 35 g. thrice weekly. This was placed, together with the other supplements, in the aluminium basins.

As will be mentioned later, a number of sheep in groups D and E died in the first months of the trial. Consequently, from the eighteenth week the intake of urea was reduced by 50 per cent. without altering the total nitrogen intake. This was accomplished by reducing the amount of urea nuts or molasses-urea mixture by half and adding half the amount of the high-protein nuts which was given to the sheep of group C.

In the second trial, when there were four groups, designated F, G, H, and J, three different supplementary rations were offered. The composition and daily allowance of these are given in Table 2.

The salt mixture was the same as that used in the first trial with the addition of 200 mg. cobalt (as cobalt sulphate) per kg. Hence each animal received approximately 1 mg. cobalt per day.

The materials for the supplements were mixed and compressed into "nuts" as before. The supplements for each group provided approximately 300 "useful" Calories per day. Those for group G provided approximately

2 g. nitrogen daily, whereas those for groups H and J provided approximately 9 g. nitrogen daily. Approximately 50 per cent. of the nitrogen of the supplements for group J was supplied by urea. The sheep of this group received approximately 25 g. urea on each of three days—Monday, Wednesday, and Friday—each week.

Table 2.

COMPOSITION OF SUPPLEMENTS AND AMOUNTS REQUIRED, SECOND TRIAL.

Material.	Group G : Low-protein.	Group H : High-protein.	Group J : Urea.
	%	%	%
Ground Wheat	40	5	25
Bloodmeal	5	65	22
Molasses	40	20	30
Urea	..	..	8
Lucerne Meal	10	5	10
Salt Mixture	5	5	5
Supplement daily (g) ..	120 ($4\frac{1}{4}$ oz.)	100 ($3\frac{1}{2}$ oz.)	135 ($4\frac{3}{4}$ oz.)
Supplement thrice weekly (g) ·	280	233	315

Heavy rains were received in January and February, 1953, and a bountiful growth of pasture occurred. This matured and dried off rapidly, as usual, but no rain fell during the succeeding winter and the pasture remained abundant and palatable through the trial. As a result, no additional supplements of grain, such as had been given in the previous year, were necessary.

(3) Methods.

Prior to the beginning of the first trial, all the sheep were weighed and were then separated into five groups, each of 25 sheep of similar weights. This was accomplished by selecting lots of five animals of approximately the same weight and distributing the individuals of each lot at random among the five groups. Thereafter, the sheep were weighed each week.

The production of wool by the individual sheep was measured over periods of approximately eight weeks by a method similar to that used previously (Peirce 1951a). However, in determining the weight of wool obtained from the defined areas on the sheep, the samples were washed in a warm, dilute solution of Lissapol-N before being extracted with ethyl ether. The areas on the right side, for determination of the weight of dry clean wool, were clipped on all sheep at the end of each 8-weekly period; those on the left side, for determination of mean fibre diameter, were clipped from eight sheep of each group on the first three occasions only.

At the end of a preliminary period of six weeks, during which the sheep were grazing but receiving no supplements, all the sheep were clipped. Regular weekly weighing of all animals and the feeding of supplements to groups B, C, and D were also begun at this time (supplements for group E did not begin until 12 weeks later).

The deaths, to be discussed later, of a number of sheep in groups D and E, which received urea, rendered necessary the transfer of some sheep from other groups in order to maintain approximately equal numbers of sheep in all the groups.

All the sheep were shorn after the trial had been in progress for 10 weeks, and the trial was terminated in March 1953, after a period of nine months.

The second trial was carried out with the 90 surviving sheep from the first trial. On the basis of their wool production in the preliminary and final periods of the first trial, they were re-allotted to four groups, each of 22 sheep. All were shorn at the end of July 1953, and in the following week the defined areas were clipped. Feeding with the appropriate supplements was then begun.

The sheep were weighed weekly. The defined areas on the right sides of eight sheep from each group were clipped, for determination of fibre diameter, at the beginning of the experiment. The areas on the left side were clipped, for estimation of weight of wool, from all sheep at the end of the first and second periods; each of these was of approximately eight weeks' duration. Owing to an error, however, the areas on the right sides of all sheep were clipped at the end of the third period. The wool so obtained, therefore, represented the growth over the whole of the trial, approximately 25 weeks. The trial was terminated at this time, the end of January 1954, as by then good summer rains had been received and an abundant growth of pasture had taken place. From previous experience it was considered that the sheep would not then consume supplements voluntarily.

In this trial, also, it was necessary to transfer some sheep from groups G and H (low-protein and high-protein) to group J (urea) in order to maintain the numbers of this last group, many of which had died.

III. RESULTS.

(1) General Well-being.

In the first trial the toxicity of fairly large amounts of urea was signally demonstrated. Twenty sheep which consumed urea-containing nuts and nine which received the molasses-urea mixture died. In contrast, only six animals in the remaining groups died—four in the control and two in the low-protein groups, respectively—and two of these six deaths were due to mechanical causes. During the first four weeks of the trial, eight sheep in group D died. The sheep of this group were in general eating only one-third to one-half of their allotted ration, but at least two of the sheep which died consumed their entire ration (supplying 36 g. urea in one feeding). Death in most cases occurred one to two hours after consumption of the nuts. The symptoms observed were similar to those described by Clark, Oyaert and Quin (1951). An abnormal stance was followed by muscular tremors, at first of the jaws and head, but later of the whole body. Inco-ordination of gait followed and later prostration of the animal with rigid extension of the limbs with occasional violent spasms. The breathing became laboured and just before death there was violent twitching of the mouth and regurgitation of the rumen contents, which frequently had a strongly ammoniacal odour. One further death occurred in group D during the next three months, although the mean consumption of nuts was only about 120 g. at each of the three feeds per week, equivalent to approximately 15 g. urea. However, during the thirteenth week all the experimental sheep accidentally gained access to the store of nuts and apparently some consumed urea-containing nuts: one hour later 11 sheep were dead. None of these animals was from the group which had been receiving urea-containing nuts.

The molasses-urea mixture did not become available until the twelfth week, and as the toxicity of urea in comparatively large amounts had been amply demonstrated by then, only one-third of the allotted dose (equivalent to 15 g. urea) was given for the first week and two-thirds of the dose (in two equal amounts separated by an interval of one hour) for the next two weeks. In the last week of dosing four sheep died. In the next two weeks five more sheep died, two having again received two-thirds of the allotted ration and the other three the full ration, containing 45 g. urea, in three doses separated by intervals of one hour and two hours. The symptoms were again similar to those already described.

From the eighteenth week onward, when the intake of urea was reduced by half, no further deaths occurred among the sheep which received urea either in the form of nuts or as a drench of molasses-urea mixture.

In the second trial, the toxicity of urea under certain circumstances was again demonstrated. Fourteen sheep receiving the urea ration died during the six months of the trial, compared with one death in the control group and three in the high-protein group. Many of the sheep refused to eat the urea and the high-protein nuts and both types were therefore ground and mixed with water and given as a drench. The sheep thus received their ration of urea (25 g.) in solution in a few minutes.

(2) Increase in Body Weight.

In the first trial during the six months when drought conditions prevailed, the sheep of groups B, C, and E maintained their comparatively low initial body weights (34–35 kg.) but those of groups A and D (control and urea supplements, respectively) lost approximately 3 kg. Climatic conditions and the resulting state of the pasture had a marked influence on body weight thereafter. Light rain was received during the first three weeks and this was followed by heavy rain during the next six weeks. The weights of the sheep declined by 1–2 kg. during the first five weeks, but with the abundant growth of pasture increased by 8–13 kg. during the final nine weeks; the mean weights of the groups when the trial terminated at the end of March were 42–44 kg.

In the second trial, the mean weights of the various groups at shearing, just prior to the commencement of the trial, ranged from 48 kg. to 50 kg. and at the end of five months were almost the same (49–51 kg.), although the sheep had been grazing on mature dry grass throughout this period. The performance of the control group, which received no supplementary fodder, was as good as that of the groups which received supplements. The summer rains then commenced, and as in the first trial the weights of the sheep declined; all groups lost about 6 kg. in the final six weeks of the experiment.

(3) Production of Wool.

The mean wool production of each group in the preliminary period and in each of the five experimental periods of the first trial has been set out in Table 3. The table also includes the mean fibre diameter of eight sheep from each group in both the preliminary and the first periods.

Table 3.

MEAN PRODUCTION OF WOOL, FIRST TRIAL.

Group.	Mean Fibre Diameter.		Dry Clean Wool Fibre on 150 sq. cm. per day.						
	Preliminary Period.	Period 1.	Preliminary Period.	Period 1.	Period 2.	Period 3.	Period 4.	Period 5.	Mean of Periods 1–4.
	μ	μ	mg.	mg.	mg.	mg.	mg.	mg.	mg.
A—Control	20·1	18·4	89	62	61	69	71	127	66
B—Low-protein	20·7	19·1	88	75	85	89	95	137	86
C—High-protein	19·7	19·3	83	77	97	102	99	130	94
D—Urea	20·5	19·0	91	69	77	83	87	141	79
E—Molasses–Urea	19·3	18·4	91	63	60	84	99	137	77

The results for period 5 will not be considered here, as ample pasture, in addition to the prepared supplements, was available to the sheep during this period. In the remaining periods the provision of supplements brought about increases in wool production above that of the control group. The urea supplements, however, did not increase the wool production above that obtained with low-protein supplements, except for a small increase (5 per cent.) in period 4 with molasses-urea. The high-protein supplement, on the other hand, in all periods brought about an increased production as compared with the low-protein supplement.

The mean wool production of each group during the various periods of the second trial has been set out in Table 4. The results from only those sheep which completed all three periods have been used, although the means for periods 1 and 2 would not have differed greatly if all sheep had been included. The mean wool production of the animals in the final period of the first trial has also been included in the table for comparison; the availability of ample green pasture, rather than the experimental treatment, was the dominant factor in the last period.

Table 4.

MEAN PRODUCTION OF WOOL, SECOND TRIAL.

Group.	Number of Sheep.	Dry Clean Wool Fibre on 150 sq. cm. per day.				First Trial, Right Sides, Period 5.
		Left Sides.			Right Sides.	
		Period 1.	Period 2.	Mean of Periods 1 and 2.	Periods 1 + 2 + 3.	
		mg.	mg.	mg.	mg.	mg.
F—Control	21	130	117	123	125	136
G—Low-protein ..	17	137	132	134	129	133
H—High-protein ..	14	131	123	127	127	141
J—Urea..	9	128	117	123	122	142

The results show that throughout the experiment the provision of the various supplements brought about but little increase in wool production above that of the unsupplemented group. This is surprising in view of the fact that the pasture consisted of mature dry grass of low protein content. Its nutritive value must have been comparatively high, however, because the wool production in this trial was 30–90 per cent. higher than in any of the periods of the first trial prior to the advent of ample green pasture.

IV. DISCUSSION.

Two disadvantages of urea became apparent in these trials—its unpalatability and its toxicity. The sheep refused to consume the full urea-containing ration, although this difficulty had not been encountered in two previous experiments with sheep in pens (Peirce 1951 a, b). This difference in behaviour could have been due to differences in the types of sheep used, but more probably was due to differences in the amount of urea offered and in the amount and nature of the remainder of the ration. In the pen experiments, urea (15 g. daily) was either mixed with chaffed lucerne hay or incorporated in proportons of 4-6 : 100 in compressed mixtures of lucerne meal and dehydrated potatoes. In the present experiment, urea (25 g. or 36 g. in one day) was offered in compressed rations of molasses and ground wheat (12 per cent. urea), or of molasses, ground wheat and bloodmeal (8 per cent. urea, 22 per cent. bloodmeal). In a later experiment with sheep in pens (Peirce 1955) the last-mentioned ration was again found to be unpalatable. However, from these experiments and additional observations, it seemed probable that factors other than the palatability *per se* of urea were involved. It has been observed that sheep sometimes readily consume urea-containing rations when these are first presented to them, but after a few days will consume a portion only of the amount which they ate on the first day. Furthermore, after a sheep has been given a drench of a mixture of molasses and urea, it has frequently been found that an interval of several hours has elapsed before the animal has commenced eating a urea-free ration of normal palatability. It is possible that when the amount of urea ingested at one time exceeds a certain figure, it exerts a detrimental effect on the rumen microflora, resulting in a reduced breakdown of the carbohydrate portion of the ration, and consequently a depression, at least temporarily, of appetite.

The possibility that, in certain amounts and under certain conditions, urea could be toxic was clearly demonstrated in the present experiment. Sheep died after having either consumed, in a period of about one hour, an amount of 36 g. urea in a compressed ration, or received in two drenches, separated by an interval of about one hour, a total amount of 30 g. urea dissolved in molasses, or received, in a period of a few minutes, an amount of 25 g. urea in a supplement which was ground and given in aqueous suspension. No deaths had occurred in the previous pen experiments (Peirce 1951 a, b) when 15 g. was consumed with a portion of the ration. While the actual amount of urea was the dominant factor in determining toxicity, other factors undoubtedly were involved. These included the time taken to consume the urea, the nature of the remainder of the ration and the individual differences inherent in all animals. The more rapidly the urea was consumed, the more toxic it appeared to be; this was seen in the number of deaths which occurred among sheep which were given solutions of urea in molasses. That the nature of the ration had an influence on the toxicity of urea could be seen in a comparison of the second of the present trials with the comparable experiment in pens (Peirce 1955). The animals in both experiments received in the same way the same amounts of similar supplements providing 25 g. urea: 60 per cent. of the sheep grazing on mature pasture died, compared with only 8 per cent. of the sheep fed on chaffed wheaten hay. Individual variations were seen in the present experiments; some animals died when they first had access to urea-containing rations, others did not die until they had received urea for a week, and still others were apparently unaffected by it.

The actual toxic agent in urea poisoning was presumed to be ammonia, formed by the hydrolysis of urea. Evidence for this belief was obtained in a number of cases where sheep in pens died after eating urea-containing rations or ingesting aqueous solutions of urea. An ammoniacal smell in the regurgitated rumen contents, or in the rumen on post-mortem examination, was frequently observed. Furthermore, in one such animal which died one hour after ingesting 45 g. urea in aqueous solution, the ammonia concentration in the blood had risen considerably; it increased from a value of $0 \cdot 7\ \gamma$ N per ml. of blood just before ingestion of the urea to 20 γ shortly before death.

In neither trial did a supplement of urea bring about an increase in wool production above that obtained with a low-protein supplement, although in previous experiments in pens (Peirce 1951 a, b) increases were observed.

There are several possible reasons for the failure of urea to increase wool production in the present experiment. All the sheep in the first trial were receiving only a maintenance level, because owing to the drought there was very little pasture, and that of poor nutritive quality, available throughout most of the trial. Hence, even if protein were synthesized by the rumen flora, some of this protein was probably being used for the supply of energy, thus reducing that available for wool production. Conditions were different in the second trial, ample pasture to meet the energy requirements of the animals being available throughout. Another contributing factor in the first trial was the poor consumption of the urea-containing nuts. The daily intake of nitrogen of the supplements consumed by this group was only one or two grams above that of the supplements of the low-protein group in all but one period, the third; here the excess was approximately 6 g. per day, without, however, any increase in wool production. The most probable reason for the lack of response to the molasses-urea mixture in the first trial and the urea-containing supplement in the second trial was the method of administration. The urea reached the rumen in solution within a few minutes and presumably was rapidly hydrolysed to ammonia, the rate at which this hydrolysis occurred being so great as to lead to inefficient utilization by the rumen microflora, with considerable loss of ammonia either by washing out from the rumen or by absorption through its wall. (This also led to the heavy mortality experienced among sheep which were given urea in solution.)

The feeding of supplements with a high protein content resulted in the first trial in an increased wool production above that obtained with a low-protein supplement, as was to be expected, but no such increase occurred in the second trial. The reason for this failure is not clear, unless again it was due to the method of administration. The supply within a few minutes of the whole of the supplementary ration, ground and suspended in water, may have had an adverse effect on the rumen microflora, with consequent reduction in the digestion of the cellulose and a corresponding demand on some of the protein for purposes other than wool production.

Both trials demonstrated that urea was not utilized by the sheep under the conditions employed, and they seemed to indicate the futility of attempting to supplement the ration of grazing sheep with urea-containing feeds given only thrice weekly. Such a procedure, involving the ingestion of a comparatively large amount of urea at one time, may render the supplements unpalatable and give rise both to increased toxicity and to poor utilization. It would seem that, to be useful for sheep, urea must be available each day, and in such form that ingestion is spread over a period of several hours. In some cases these objectives can possibly be achieved by spraying mature pasture with a mixture of molasses and urea. Another way in which the problem may be attacked is by the use of a nitrogenous compound which is less rapidly hydrolysed to ammonia than is urea. This approach seems well worth investigating.

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