THE UTILIZATION OF UREA

IN THE FATTENING RATION

OF THE STEER

THE UTILIZATION OF UREA
IN THE FATTENING RATION
OF THE STEER

By

CLIFFORD E. KINNEY

Bachelor of Science

Oklahoma Agricultural and Mechanical College

1934

Submitted to the Department of Animal Husbandry

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

For the degree of

MASTER OF SCIENCE

1946

APPROVED BY:

Chairman, Thesis Committee

Member of the Thesis Committee

Head of the Department

Dean of the Graduate School

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Hilton M. Briggs, Professor of Animal Husbandry, for his guidance and counsel during the course of the experiment and the preparation of this thesis.

He wishes to express his appreciation to Dr. W. D. Gallup, of the Agricultural Chemistry Department, for making the chemical analyses reported.

Acknowledgement is given E. I. Du Pont De Nemours and Company, whose financial grant helped to make this study possible.

PREFACE

Protein is the most expensive feed ingredient in the ration of cattle. Protein sources for cattle feed have reached a critical stage in recent years because of the reduced acreage of cotton and other protein producing crops, increased numbers of livestock, and the demand for the protein bearing sources by manufacturing industries. It is, therefore, a matter of real importance to find substitutes or extenders for protein in cattle rations so that our meat supply will not suffer.

Experiments have been carried out over a period of years in various countries testing simple non-protein nitrogenous compounds as substitutes for protein. The effects of substituting urea, ammonium salts, amino acids, and various amides for all or a portion of the natural protein in the ration have been tested with dairy cattle, goats, heifers, steers, sheep, and human beings. In recent years the feeding of urea to ruminants as a source of protein has received considerable study by various investigators both here and abroad. Some conflicting results have been obtained, but in general, it is conceded that urea can be utilized to some extent by ruminants as a source of protein. It has been suggested that the reason urea and related non-protein compounds are able to substitute for protein is that certain micro-organisms, normally present in the rumen, are able to convert this nitrogen to protein. These organisms are then thought to be digested lower down in the alimentary tract, making available their protein as amino acids.

The fact that sources of synthetic urea have become available in the United States in rather large volume gives us good reason for investigating, to the fullest extent, all of the possibilities of using it as a substitute for other protein sources. Cottonseed meal has long been one of the chief sources of protein for cattle in this part of the United States, but recently a shortage of cottonseed meal has become critical. A series of experiments are under way at the Oklahoma Experiment Station to determine to what extent urea can be used as a partial substitute for cottonseed meal in rations for lambs and beef cattle.

TABLE OF CONTENTS

REVIEW OF LITERATURE

The idea that protein may be synthesized by micro-organisms present in the digestive tract of herbivora was first suggested by Zuntz (1891). Hagemann (1891) suggested that the protein formed in the bodies of the micro-organisms is digested farther down the digestive tract by the host. The possibility that micro-organisms of the digestive tract may be a desirable source of protein for the host was later substantiated by Muller (1906) who investigated the nutritive value of the protein of the microbe from a culture taken from rumen contents and found it to be equal to "blood albumin" for the dog. Henriques and Anderson (1914) successfully reared young rats on a diet in which their only source of protein was washed bacteria from a culture obtained from rumen contents. Johnson, Hamilton, Robinson, and Garey (1944) found that a bacterial fraction obtained by culture of synthetic media, contained 58.81 per cent protein. The biological value of this bacterial protein, when fed to rats, was 66 per cent and its true digestibility was 82.4 per cent.

Just how and to what extent conversion of non-protein substances to protein in the paunch of ruminants takes place has been the object of considerable investigation in recent years. Hart, Bohstedt, Deobold, and Wegner (1939) used the rumen fistula technique to study the rate of synthesis of protein in the rumen of a heifer as indicated by the disappearance of added urea and ammonium salts. By varying the protein content of the ration, they found that the rate of conversion was rapid at a level of protein of 12 per cent in the ration and decreased rapidly at a level of 18 per cent or over. Conversion "in vitro" was shown to take place when ammonium salts were added to extracts of rumen contents and incubated.

Wegner and others (1941) found that urea nitrogen or ammonia nitrogen, when ingested as 1 to 5 per cent of the dry matter of the ration, disappeared from the rumen in 4 to 6 hours after feeding. This experiment showed that a definite increase in the percentage of protein nitrogen of the rumen ingesta was produced by adding 5 per cent urea to a low nitrogen basal ration.

Pearson and Smith (1943) studied "in vitro" the liquid rumen contents taken from a gastric fistula of a steer. Using incubation periods of only 2 to 4 hours, and adding urea to the liquid before incubation, they found that synthesis of protein occurred at a rate of about 9 mg. of nitrogen per 100 grams of rumen liquid. While the total nitrogen of the liquid remained constant, there was a decrease in the non-protein nitrogen (made up mostly of urea and ammonia) but the greater decrease was in the ammonia nitrogen, suggesting that the protein synthesis was from ammonia rather than from urea.

Fingerling and his associates (1937) showed in nitrogen balance experiments with steers that when urea was used as a supplement to a low protein ration that 50 to 61 per cent of the urea nitrogen could be utilized. To determine whether bacteria or protozoa are responsible for this synthesis of protein from urea was one of the objects of experiments by Johnson, Hamilton, Robinson, and Garey (1944). When the paunches of lambs were kept free of protozoa for 30 days, they found that these lambs utilized the nitrogen of urea containing rations to about the same extent as did normal growing lambs. This would indicate that the synthesis of protein from urea was brought about by the action of bacteria and not by the protozoa present.

The synthesis of protein from urea in the rumen seems to be at least partially dependent upon the contents of the ration. Mills and others (1942), using a heifer with a rumen fistula, found that when starch was added to a ration of timothy hay and urea, the protein of the rumen contents increased by 57 per cent. When casein was added to a diet of timothy hay, starch, and urea, the synthesis of protein from urea in the rumen was nearly abolished. Johnson, Hamilton, Mitchell, and Robinson (1942) found that supplements of corn molasses enhance the utilization of urea nitrogen in sheep. Mills, Lardinois, Rupel, and Hart (1944) obtained results in experiments with heifer calves and cows which indicated that the most effective utilization of urea takes place only when certain grain proteins and starch are present in the ration. The results of their fistula experiments indicated that only partial utilization of urea by ruminants occurred when molasses was the chief source of readily fermentable carbohydrate. The results of this experiment do not contradict those by Johnson and his co-workers (1942) but indicate that a combination of urea and molasses is less efficient than a combination of urea and starch.

Some experiments have shown the effects of urea ingestion upon the digestibility of various components of the ration. Harris and Mitchell (1941b), in their experiments with lambs, secured results which showed that the addition of urea to a low nitrogen basal ration increased the digestibility of cellulose from 17.8 per cent to 38.7 per cent. The digestibility of the dry matter, when urea was added to the low nitrogen basal ration, was 65.8 per cent as compared with 66.9 per cent when an equal amount of nitrogen from casein was added. The apparent digestibility of urea nitrogen itself was 37.7 per cent and its true digestibility 88.8 per cent as compared to 38.0 per cent and 86.9 per cent respectively for the casein nitrogen.

The nitrogen in the products formed from urea in the paunches of sheep is not so well digested as the nitrogen from casein according to

Johnson, Hamilton, Mitchell, and Robinson (1942). However, they found the nitrogen in the products formed from urea to be as well utilized in metabolism as the nitrogen from soybean meal and somewhat better utilized, even though not as well digested, as that from casein.

Loosli and McCay (1943), in their experiments with young calves, found the apparent digestibility of dry matter and carbohydrates to be from 74 to 80 per cent when urea was fed in sufficient amounts to raise the protein equivalent of the ration from 4.4 per cent to 16.2 per cent. The apparent digestion coefficients of dry matter and carbohydrates were from 57 to 63 per cent when the low protein basal ration was fed. The apparent digestibility of nitrogen increased greatly when urea was added to the low nitrogen basal ration.

Briggs and co-workers (1945) conducted digestion and metabolism studies with steers and secured results which showed that urea nitrogen, when used to replace 25 to 50 per cent of the nitrogen of cottonseed meal in a maintenance ration, did not significantly affect the digestibility of the various organic nutrients in the ration. Amounts of urea supplying more than 50 per cent of the total supplementary nitrogen tended to have a depressing effect on the apparent digestion of organic constituents. When 10 pounds of prairie hay was supplemented with any one of the urea supplements or with cottonseed meal, the apparent digestion coefficient of crude protein was raised from -0.9 to approximately 60.0 per cent and the nitrogen storage increased from a -10.5 per cent to about 16 per cent.

Lardinois, Mills, Elvehjem, and Hart (1944) studied the correlation between added nitrogen and carbohydrate on the vitamin synthesis in the rumen. They secured results which showed that the addition of urea as a source of nitrogen definitely increased the synthesis of riboflavin, nicotinic acid, biotin, and pantothenic acid in the bovine rumen when a readily available carbohydrate was present.

The extent to which urea may be used by ruminants in satisfying maintenance, growth, and production requirements has received considerable study. Bartlett and Cotton (1938), in a 142 day feeding experiment with twenty-one dairy heifers, found that the addition of 0.127 pounds per animal per day of urea to a diet supplying a limited amount of protein resulted in an extra daily live-weight increase of 0.24 pounds per day. This increase was statistically significant so it was concluded that the animals must have utilized the urea nitrogen in their metabolism. In this experiment animals receiving the same quantity of additional nitrogen in the form of ground nut protein showed increased but not significantly greater live-weight gains than those receiving the urea.

Hart et al. (1939) conducted experiments with 10 growing calves and demonstrated that urea nitrogen can be utilized at least for a partial supply of protein nitrogen. With urea nitrogen constituting 43 per cent of the nitrogen of the ration the growth rate was but slightly less than that secured with a ration containing 66 per cent of its nitrogen as casein nitrogen. When casein nitrogen constituted 43 per cent of the total nitrogen of the ration, the growth rate over a period of 16 weeks was 1.5 pounds daily as compared with 1.3 pounds daily for the comparable level of urea nitrogen.

Harris and Mitchell (1941a) concluded that sheep may be maintained in body and nitrogen equilibrium for over 100 days on rations containing urea and only enough protein to provide one-tenth the amount of nitrogen needed for equilibrium. They found that 202 mg. of urea nitrogen and 161 mg. of casein nitrogen per kilogram of body weight will maintain nitrogen equilibrium in sheep. It was determined that the biological value of urea at nitrogen equilibrium was 62 as compared with 79 for casein nitrogen. Harris and Mitchell (1941b) in another experiment secured nearly normal growth in lambs by the addition of urea to a low nitrogen ration which was unable to support appreciable growth or even consistently to maintain nitrogen equilibrium. They concluded that such a ration need not contain more than 11 per cent of conventional protein in which urea furnishes 50 per cent of the nitrogen.

Johnson, Hamilton, Mitchell, and Robinson (1942) found that the addition of urea to a low nitrogen basal ration, in amounts to produce the equivalent of 12 per cent of crude protein on a dry matter basis, induced a retention of nitrogen in growing lambs that cannot be bettered by further additions of urea but can be bettered by raising the true protein content of the ration. These results indicate that urea will not meet all the protein requirements for growth in sheep.

Loosli and McCay (1943), studying the utilization of urea by young calves, found that those on a low protein ration containing only 4.4 per cent protein failed to grow while the calves receiving urea sufficient to bring the protein equivalent to 16.2 per cent gained 61 pounds in two months as compared with 80 pounds gained by calves treated in a similar manner but fed a normal ration. Calves as young as two months of age were able to make fair gains in weight when urea constituted three-fourths of the total nitrogen of the ration. The calves fed the low protein basal ration were in negative nitrogen balance while those receiving the added urea were in a positive nitrogen balance, retaining 24 per cent and 36 per cent of the ingested nitrogen.

In a review of German literature by Axelsson (1942) it was stated that about one-third of the nitrogen of normal rations can be replaced by urea for maintenance and growth of ruminants and about one-half of the nitrogen of rations for milk production if the energy supply is maintained.

In feeding trials with 24 dairy cows Rupel, Bohstedt, and Hart (1943) secured results which would indicate that the nitrogen from urea is utilized nearly as effectively as the nitrogen from linseed meal. Urea fed at a level of 1 per cent of the dry matter of the entire ration or 3 per cent of a concentrate mixture substituted effectively for the linseed meal used in the control ration.

Murry and Romyn (1939) found that when either all or one-half of the protein of peanut cake was replaced by urea (nitrogen equivalent) in the ration of young Red Polled heifers the weight increases, over a period of 93 days, were approximately the same as when the ration was supplemented entirely with peanut cake.

Owen, Smith, and Wright (1943) studied the use of urea as a partial substitute for blood meal in the feeding of dairy cattle. They used seven lactating Ayrshire cows over a period varying from 100 to 160 days. When one-third of the nitrogen of blood meal supplement was replaced by an equal amount of nitrogen in the form of urea the milk yields of five of the seven cows were well maintained. With four of the five cows under test a rapid and significant decrease in milk yield took place when urea was removed from the feed. They found no significant difference in the composition of the milk.

The Oklahoma Experiment Station (1945) conducted experiments for the purpose of studying the performance of fattening beef calves when supplemented with cottonseed meal and urea containing supplements. Three lots of ten head each were fed corn and prairie hay plus supplements of Formula 1, Formula 2, or cottonseed meal for a period of 153 days. Formula 1 had 25 per cent of its nitrogen in the form of urea and Formula 2 had 50 per cent of its nitrogen in the form of urea. Results secured in this fattening experiment showed that calves supplemented with the urea containing pellets had an average daily gain comparable with the calves fed the cottonseed meal supplement. The calves receiving 25 per cent of their supplemental protein nitrogen in the form of urea gained 1.96 pounds daily as compared with 1.98 pounds daily for those receiving 50 per cent of their supplemental nitrogen in the form of urea and 1.81 pounds daily for those supplemented with cottonseed meal. There was very little difference in the amount of feed required per 100 pounds of gain, but calves supplemented with Formula 2 had the lowest feed requirement and those receiving cottonseed meal had the highest feed requirement.

In a more recent fattening experiment at the Oklahoma Station (1946) covering a period of 167 days, it was found that younger calves supplemented with cottonseed meal gained a bit faster on slightly less feed per 100 pounds gain than calves supplemented with either 25 or 50 per cent urea containing pellets. The average daily gains secured were 1.86 pounds for those supplemented with cottonseed meal, 1.77 pounds for the calves getting 25 per cent of their supplemental nitrogen from urea, and 1.61 pounds for those receiving 50 per cent of their supplemental nitrogen in the form of urea.

In two wintering experiments with two lots of eight head each of high grade Hereford heifers, Briggs and co-workers (1945, 1946) secured results which showed that yearling heifers can be wintered as satisfactorily on pellets containing 25 per cent urea nitrogen as on cottonseed meal when both are fed as supplements to range grass. In the first experiment, heifers receiving the urea containing pellets gained .28 pounds daily as compared with .26 pounds gained daily by those getting cottonseed meal. In the second experiment, the heifers getting the urea pellets gained 0.33 pounds daily and those receiving cottonseed meal gained 0.29 pounds per day.

OBJECT OF THE EXPERIMENT

Digestion and metabolism studies have been conducted with three good grade Hereford steers for the purpose of determining if urea nitrogen may replace a part of the nitrogen of cottonseed meal without affecting the digestibility of a steer fattening ration.

EXPERIMENTAL METHODS AND PROCEDURE

Three separate metabolism trials were run during the experiment and three steers were used in each trial. In each trial a ten day collection period followed a ten day preliminary feeding period.

Animals Used

Three good grade Hereford steers weighing approximately 640 pounds were used as subjects in the experiment. They had been used in some previous trials and were accustomed to the stanchions and harness. All of the steers were about of the same quality and in about the same general condition.

Equipment

Individual stanchions with false bottom floors and separate and nearly enclosed feed boxes were used. A removable box behind each steer was used for collection of the feces. A rubber funnel with harness attached to keep it in place and a hose running into a 5 gallon can located directly beneath the floor of each stanchion was used for the collection of urine from each steer. Glass jars with tight fitting lids were used for keeping aliquots of urine and feces and the jars were stored in an electric refrigerator at about 34° F. The scales used for weighing feces and hay were O'Haus lever balance scales while direct reading Toledo balance scales were used for weighing of the concentrates. Daily urine volumes were obtained by measuring in graduated cylinders.

Rations

The three rations fed during the experiment are given in Table 1.

Table 1. The daily rations fed steers in a metabolism trial.

	Ration A	Ration B	Ration C
Ground yellow corn	5454 gms.	5454 gms.	5454 gms.
Prairie hay	964 gms.	964 gms.	964 gms.
Cottonseed meal	794 gms.		
Urea Formula 1 (25% Urea N.)		794 gms.	
Urea Formula 2 (50% Urea N.)			794 gms.

The corn fed in the experiment was medium ground yellow corn while the prairie hay was of poor quality with little bluestem grass predominating. The cottonseed meal used was of 43 per cent protein grade. The urea containing pellets consisted of the following:

Formula 1

10% Blackstrap molasses
4% Dupont's 262
11% Hominy feed
75% Cottonseed meal

Formula 2

10% Blackstrap molasses
8% Dupont's 262
32% Hominy feed
50% Cottonseed meal

Dupont's 262 had a crude protein equivalent of 262 per cent (N. x 6.25). It consisted of crystaline urea, red dog flour, and dolomitic limestone. The red dog flour and dolomitic limestone were added for the purpose of making it a free running product. The cubes designated as Formula 1 and Formula 2 were in pellet form and were manufactured especially for the experiment by Nutrena Mills, Inc., at their Coffeyville, Kansas plant. The cottonseed meal was the standard fine ground product commonly sold on the market.

Chemical analyses of the feed used in this experiment are shown in Table 2. All analyses were made by the Agricultural Chemistry Department of the Oklahoma Experiment Station using methods approved by the Association of Official Agricultural Chemists (1940).

Table 2. The chemical composition of feeds used in the metabolism study.

		On dry matter basis						
Feed	Dry Matter	Organic Dry Matter	Protein	Ether-Extract	Fiber	N.F.E.	Nitrogen	Ash
	%	%	%	%	%	%	%	%
Corn	88.82	98.54	8.73	5.07	2.13	82.61	1.40	1.46
Cottonseed meal	91.21	94.11	45.24	6.91	10.01	31.95	7.24	5.89
Formula 1 (25% Urea N.)	90.68	93.68	45.97	6.18	7.92	33.61	7.36	6.32
Formula 2 (50% Urea N.)	89.37	95.03	47.00	5.09	5.66	37.28	7.52	4.97
Prairie hay (Trial 1)	92.53	92.82	4.94	2.05	35.19	50.64	0.79	7.18
Prairie hay (Trial 2)	93.80	91.66	4.40	2.21	35.03	50.02	0.70	8.34
Prairie hay (Trial 3)	94.34	93.53	4.57	2.14	34.38	52.44	0.73	6.47

Method of Feeding

The steers were hand fed twice daily at approximately 7:00 a.m. and 5:00 p.m. The concentrate mixture was carefully weighed for each steer to the nearest gram. The hay was weighed to the nearest ounce.

The feeding schedule followed for the three trials is shown in Table 3.

Table 3. The feeding schedule used in the metabolism study.

Steer No.	Rations Fed Trial 1	Trial 2	Trial 3
5	A (C.S.M. Supplement)	C (50% Urea N. Supplement)	B (25% Urea N. Supplement)
7	B (25% Urea N. Supplement)	A (C.S.M. Supplement)	C (50% Urea N. Supplement)
8	C (50% Urea N. Supplement)	B (25% Urea N. Supplement)	A (C.S.M. Supplement)

In following the above procedure of rotating the rations, each of the steers received each of the three different rations during one feeding trial. No feed was removed from the bunks during the ten day collection periods. At the end of each ten day collection period the orts were removed, weighed and a chemical analysis made. The steers were watered from a bucket twice daily while block salt was kept before the steers at all times.

Collections

Feces were allowed to drop in a wooden box behind each steer. A caretaker was on hand to remove the feces from the box at frequent intervals and to place them in covered galvanized cans. The urine was collected in cans beneath the false bottom floors of each stall. At approximately 2:00 p.m. each day, the feces were weighed and the urine measured for each steer. A representative 2 per cent aliquot was taken of the daily feces and urine excretions, placed in separate numbered glass jars, and stored in the refrigerator. In order to reduce nitrogen losses and to preserve the samples, feces samples were treated with thymol solution before storage and the urine samples had concentrated sulphuric acid and thymol crystals added before storage. At the end of the ten day collection period, the aliquots were taken to the laboratory and analyzed.

The daily amounts and chemical analyses of feces, urine, and orts are shown in Table 4.

Table 4. The daily amounts and chemical analyses of feces, urine and orts in a digestion and metabolism study with steers.

Supplement	Steer No.	Trial	Material	Daily Amounts	Dry Matter	Protein	Ether-Extract	Crude Fiber	Nitrogen Free-Extract	Nitrogen	Ash	Urine Nitrogen Gms. Per Liter
					Composition of Dry Matter							
					%	%	%	%		%	%	
	5	1	Feces	7650 gms	28.20	15.78	6.98	16.91	52.11	2.52	8.22	
			Urine	3037 ml								11.86
			Orts	None								
Cotton-seed Meal	7	2	Feces	7354 gms	27.64	17.93	3.85	12.89	58.47	2.87	6.86	
			Urine	2854 ml								14.36
			Orts	None								
	8	3	Feces	6703 gms	29.92	16.01	2.78	12.45	63.48	2.56	5.28	
			Urine	3855 ml								12.46
			Orts	None								
	5	3	Feces	6812 gms	27.84	16.48	2.61	12.71	62.59	2.64	5.61	
			Urine	3748 ml								11.26
Formula 1 (25% Urea N.)			Orts	None								
	7	1	Feces	6372 gms	26.04	16.42	5.50	15.67	55.37	2.63	7.04	
			Urine	2470 ml								12.08
			Orts	635 gms	92.47	8.35	3.36	7.05	62.69	1.34	18.55	
	8	2	Feces	5394 gms	30.36	16.08	3.62	12.82	60.86	2.57	6.62	
			Urine	2500 ml								16.46
			Orts	232 gms	90.66	9.38	4.60	8.54	74.28	1.50	3.20	
	5	2	Feces	5915 gms	28.92	14.93	2.79	13.77	61.96	2.39	6.55	
			Urine	3475 ml								10.92
			Orts	None								
Formula 2 (50% Urea N.)	7	3	Feces	7343 gms	26.80	17.84	4.32	11.73	59.52	2.85	6.59	
			Urine	3258 ml								17.10
			Orts	None								
	8	1	Feces	6368 gms	28.32	14.96	2.93	13.63	62.55	2.39	5.93	
			Urine	2862 ml								12.68
			Orts	165 gms	90.53	12.29	4.39	4.90	74.63	1.97	3.79	

Table 5. The effect of cottonseed meal and urea containing supplements on the apparent digestibility (per cent) of steer fattening rations in the metabolism study.

Steer No.	Protein Digestion Coefficient for Ration			Ether-Extract Digestion Coefficient for Ration			Crude Fiber Digestion Coefficient for Ration			Nitrogen-Free-Extract Digestion Coefficient for Ration			Organic Dry Matter Digestion Coefficient for Ration		
	Supplement Fed														
	C.S.M.	Formula 1 (Urea 25%)	Formula 2 (Urea 50%)	C.S.M.	Formula 1	Formula 2	C.S.M.	Formula 1	Formula 2	C.S.M.	Formula 1	Formula 2	C.S.M.	Formula 1	Formula 2
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
5	57.2	60.7	67.9	52.0	84.0	84.2	25.5	49.0	48.8	76.0	74.9	77.5	68.5	71.6	74.5
7	53.9	63.6	56.0	75.2	68.4	71.8	46.8	39.9	49.4	74.6	78.8	75.3	69.9	73.4	70.8
8	59.5	66.0	65.5	82.3	80.3	82.0	48.9	54.3	45.4	73.0	78.0	75.5	69.9	74.8	72.3
Average	56.9	63.4	63.1	69.8	77.6	79.3	40.4	47.7	47.9	74.5	77.2	76.1	69.4	73.3	72.5

RESULTS

Table 5 presents the apparent digestion coefficients secured in each trial. The data presented in Table 5 were analyzed by the analysis of variance method presented by Snedecor (1937). The digestion coefficients of each nutrient were studied separately.

The Effect of Urea and Cottonseed Meal on Protein Digestion

The apparent digestion coefficients of the protein in the three rations are shown in Table 5. During the three trials the feeding of Formula 1 (25% Urea N.) resulted in an average apparent protein digestion coefficient of 63.4 per cent as compared with a coefficient of 63.1 per cent when Formula 2 (50% Urea N.) was fed. This difference is not significant. When cottonseed meal was fed as the protein supplement of the ration, the apparent digestion coefficient of protein was 56.9 per cent. This was 6.5 per cent less than when Formula 1 was fed and 6.2 per cent less than when Formula 2 was fed. All of the steers had a higher apparent protein digestion coefficient when they were on one of the two urea rations than when they were on cottonseed meal; however, when Snedecor's methods of analysis were applied to the results, the differences were not significant.

The Effect of Urea and Cottonseed Meal on the Digestion of Ether-Extract

There was considerable variation in the apparent ether-extract digestion coefficients in the three trials. This may be accounted for by the rather low amount of fat in the entire ration which would be magnified by a slight error in collections or chemical analysis.

Although the average apparent ether-extract digestion coefficients favored the rations containing urea, two of the three steers had higher coefficients when on cottonseed meal alone than when they were on the urea rations. The average apparent ether-extract digestion coefficients for the three rations were 69.8 per cent for cottonseed meal ration, 77.6 per cent for the ration containing Formula 1, and 79.3 per cent for the ration supplemented by Formula 2. These differences of 7.8 and 9.5 were not significant.

The Effect of Urea and Cottonseed Meal on Crude Fiber Digestion

There was no significant difference between the apparent crude fiber digestion coefficients of the rations when Formula 1 and Formula 2 were fed as the protein supplement. The average apparent digestion coefficient of crude fiber was 47.7 per cent when Formula 1 was fed and was 47.9 per cent when Formula 2 was fed. When cottonseed meal was used as the protein supplement, the average apparent crude fiber digestion coefficient was 40.7 per cent. These differences of 7.0 and 7.2 per cent were not significant.

Steer No. 5 had an apparent crude fiber digestion coefficient of only 25.5 per cent while on cottonseed meal as compared with 49.0 and 48.8 per cent respectively while on Formula 1 and Formula 2. No observation was made which would explain this wide discrepancy. This steer had a correspondingly low ether-extract digestion coefficient during the same period.

The Effect of Urea and Cottonseed Meal on Nitrogen-Free-Extract Digestion

There were no significant differences in the apparent digestion coefficients of nitrogen-free-extract for the three rations. The average digestion coefficients were 74.5 per cent for the cottonseed meal ration, 77.2 per cent for the ration containing Formula 1 and 76.1 per cent for ration containing Formula 2; this was a slight increase in favor of the rations containing urea. The apparent nitrogen-free-extract digestion coefficients were quite uniform for all the steers throughout this experiment.

The Effect of Urea and Cottonseed Meal on Organic Dry Matter Digestion

The results of the three trials show a slight advantage of the urea containing rations as compared to cottonseed meal on the digestion of organic dry matter. The ration containing Formula 1 had an apparent organic dry matter digestion coefficient of 73.3 as compared with 72.5 per cent for Formula 2 and 69.4 per cent for cottonseed meal. In each of the three trials the apparent digestion coefficients for organic dry matter were higher for the rations containing a portion of the nitrogen in the form of urea than for rations containing only cottonseed meal as the protein supplement. The differences between the three rations, although uniform, were not significant.

The Effect of Urea and Cottonseed Meal on Protein and Nitrogen Utilization

Data on nitrogen and protein utilization are given in Table 6.

Table 6. The nitrogen balance data and biological values of protein for steers fed fattening rations supplemented with cottonseed meal or urea containing supplements.

Supplement	Steer No.	Average Body Weight	Dry Matter Intake	Nitrogen Intake	Fecal Nitrogen	Estimated Metabolic Nitrogen[1]	Feed Nitrogen in Feces	Absorbed Nitrogen	Nitrogen in Urine	Endogenous Nitrogen[1]	Feed Nitrogen in Urine	Feed Nitrogen Utilized	Total Nitrogen Stored	Nitrogen Stored	Biological Values
		Kgms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	%	
Cottonseed Meal	5	301.4	6460.4	127.1	54.5	34.2	20.3	106.8	36.0	7.9	28.1	78.7	36.6	28.8	74
	7	281.4	6472.6	126.4	58.3	34.3	24.0	102.4	41.0	7.6	33.4	69.0	27.1	21.4	67
	8	306.4	6477.8	126.7	51.4	34.3	17.1	109.6	48.0	7.9	40.1	69.5	27.3	21.5	63
	Average		6470.3	126.7	54.7	34.2	20.5	106.3	41.7	7.8	33.9	72.4	30.3	23.9	68
Formula 1 (25% Urea N.)	5	347.5	6473.6	127.3	50.0	34.3	15.7	111.6	42.2	8.3	33.9	77.7	35.1	27.6	70
	7	273.1	5869.0	119.8	43.6	31.1	12.5	107.3	29.8	7.5	22.3	85.0	46.4	38.7	79
	8	289.9	6258.1	123.8	42.1	33.2	8.9	114.9	41.1	7.7	33.4	81.5	40.6	32.8	71
	Average		6200.2	123.6	45.2	32.9	12.4	111.3	37.7	7.8	29.9	81.4	40.7	33.0	73
Formula 2 (50% Urea N.)	5	321.9	6458.0	127.4	40.9	34.2	6.7	120.7	37.9	8.0	29.9	90.8	48.6	38.1	75
	7	299.1	6463.2	127.7	56.2	34.2	22.0	105.7	55.7	7.8	47.9	57.8	15.8	12.4	55
	8	271.7	6296.4	125.1	43.2	33.4	9.8	115.3	36.3	7.5	28.8	86.5	45.6	36.5	75
	Average		6405.9	126.7	46.8	33.9	12.8	113.9	43.3	7.8	35.5	78.4	36.7	29.0	68

[1]Endogenous nitrogen and metabolic nitrogen were determined by using the values of Swanson and Herman (Mo. Agr. Exp. Sta. Res. Bul. No. 372) that endogenous nitrogen is equal to $.712W^{0.42}$ and metabolic nitrogen is equal to 5.3 grams per kilogram of dry matter intake.

All of the steers were in positive nitrogen balance during each of the three trials. Nitrogen storage averaged 23.9 per cent, 33.0 per cent, and 29.0 per cent when the rations were supplemented with cottonseed meal, Formula 1, and Formula 2 respectively. Although these results favor the rations containing urea, the variation within rations was so great the differences were not significant.

There were no significant differences among the biological value of the proteins of the three rations. When cottonseed meal was fed as the protein supplement, the biological value of the protein in the entire ration was 68 as compared to 73 when Formula 1 supplied 25 per cent of the nitrogen in the form of urea and 68 when 50 per cent of the supplemental nitrogen came from urea.

DISCUSSION

Results secured in this experiment indicate that urea nitrogen may be used to replace at least 50 per cent of the nitrogen of a cottonseed meal protein supplement in a steer fattening ration without significantly affecting the apparent digestibility of any of the organic constituents in the ration. These results are in agreement with dry lot fattening experiments with beef calves conducted at this Station (1945, 1946). In those experiments calves receiving urea containing pellets similar to those used in this digestion and metabolism study, in which 25 and 50 per cent of the supplemental nitrogen came from urea and the remainder from cottonseed meal, made just as much daily gain as those supplemented entirely with cottonseed meal. Since there is close agreement in the results of these two types of feeding experiments, it would appear that the utilization of the various nutrients which promote gain is not affected by the substitution of urea nitrogen for part of the supplemental cottonseed meal nitrogen.

The substitution of urea for part of the cottonseed meal did not change the biological value of the protein in the ration, nor was there any significant change in the per cent of nitrogen retained. It seems likely, therefore, that the urea nitrogen was utilized just as effectively as the nitrogen of cottonseed meal. The reason for this excellent utilization of urea may be found in the type of fattening ration that was fed. Mills et al. (1944) showed that the most effective utilization of urea takes place only when certain grain proteins and starches are present in the ration of cows. Johnson et al. (1942) secured results which showed that supplements of corn molasses enhance the utilization of urea nitrogen in sheep. It seems likely that the ration fed in this metabolism study consisting of molasses, hominy feed, ground corn, cottonseed meal, and prairie hay furnished an excellent medium for the growth of micro-organisms in the rumen of the steers and that these micro-organisms effectively converted the urea nitrogen into usable protein nitrogen.

Whether the utilization of the urea nitrogen would have been so high is doubtful if there had been a higher percentage of total protein (N. x 6.25) in the ration. The ration fed contained only about 12 per cent crude protein on a dry matter basis. Hart et al. (1939) showed, by means of a rumen fistula in a heifer, that rapid conversion of urea and ammonium salts to protein took place at a protein level of 12 per cent in the ration and decreased rapidly at a level of 18 per cent or over. Johnson et al. (1942) found that the addition of urea to a low nitrogen basal ration for sheep, in amounts to produce the equivalent of 12 per cent of crude protein (N. x 6.25), induced a retention of nitrogen that can only be bettered by raising the true protein content of the ration. It seems probable, therefore, that the utilization of urea nitrogen in this digestion and metabolism study would have been less efficient if the protein level of the ration had been increased to the level recommended by Morrison (1945). The nutritive ratio of the rations fed in this experiment, calculated from the apparent digestibility of organic nutrients, ranged from 1:8.6 for the two urea containing rations to 1:9.0 for the ration supplemented entirely with cottonseed meal. Morrison (1945) recommends a nutritive ratio between 1:7.0 and 1:8.0 for 600 to 700 pound fattening steers. The rations fed in this experiment are a bit wide but had given very good performance in fattening calves at this Station (1945).

The apparent digestibility of ether-extract, nitrogen-free-extract, and organic dry matter was considerably higher in this trial than was obtained by Briggs and co-workers (1945) when urea nitrogen was used as a partial substitute for cottonseed meal in a maintenance ration for steers. This can be accounted for by the presence in the fattening ration of much larger amounts of more easily digestible materials in the form of molasses, hominy feed, and ground corn. The fact that digestion of crude fiber in the maintenance ration was higher than that in the fattening ration may be explained on the basis that the presence of more easily digestible carbohydrates decreases the digestibility of crude fiber. (Maynard. 1937).

The ration supplemented with cottonseed meal was a bit more palatable than the rations containing urea supplements. The No. 5 steer ate all the feed that was put before him in each trial, while No. 7 failed to eat 9 per cent of his feed when supplemented with 25 per cent urea containing pellets. The No. 8 steer left 3.4 per cent of his feed when supplemented with Formula 1 and about 2.1 per cent when fed Formula 2. These results are in line with observations made by Briggs and co-workers (1945) that the presence of urea in a ration makes the ration less palatable for steers. It is thought, therefore, that care must be exercised in making rations more palatable when urea is to be included in the ration.

The T.D.N. requirement for fattening steers in this weight class is from 10.3 to 14.0 pounds daily according to Morrison (1945). In this experiment, the T.D.N. values were calculated on the basis of the apparent digestion coefficients secured for each nutrient. It was found that the ration supplemented with cottonseed meal supplied 10.2 pounds of T.D.N. daily or amounts equal to 64.3 per cent of the total feed consumed. The ration supplemented with Formula 1 and Formula 2 supplied 10.4 and 10.6 pounds of T.D.N. daily or a percentage of 68.3 and 67.3 respectively of the feed consumed.

All of the steers gained in weight throughout the entire experiment. Weight increases were measured during each collection period and it was evident that the steers layed on fat readily regardless of which of the three rations they were consuming.

There was no evidence of pathological effects resulting from any of the rations fed. All of the steers excreted both feces and urine normally, and there were no significant differences in amounts of urine excreted by the steers on the three different rations.

Whether or not urea nitrogen can be an economical substitute for cottonseed meal nitrogen depends upon several factors. The cost of manufacturing urea containing supplements, the prices charged for cottonseed meal, and the results secured in feeding each type of supplement all enter into the problem. In this trial the amounts of actual urea nitrogen fed were only 0.42 and 0.82 per cent of the total dry matter intakes of the two urea rations. These amounts effectively replaced 25 and 50 per cent respectively of the total cottonseed meal supplement when Formula 1 and Formula 2 were used as a protein supplement. This means that 0.104 pounds of crystalline urea replaced 0.708 pounds of cottonseed meal in Formula 1 and that 0.205 pounds of urea replaced 1.4 pounds of cottonseed meal in Formula 2. However, data indicating urea to be seven times as efficient as cottonseed meal, pound for pound, are a bit misleading. It is necessary to add feeds which supply additional energy to the supplement when urea is used to replace cottonseed meal. This is because urea contains no energy supplying nutrients while cottonseed meal contains considerable amounts. The net energy was maintained in Formula 1 and Formula 2 of this trial by the addition of molasses and hominy feed to the urea supplements.

SUMMARY

Digestion and metabolism studies have been conducted on three yearling Hereford steers for the purpose of determining to what extent urea nitrogen, when used as a 25 and 50 per cent partial substitute for cottonseed meal nitrogen, will affect the digestibility of a steer fattening ration. In each of three trials, a ten day preliminary feeding period was followed by a ten day period during which collection of feces and urine was made.

It may be concluded from results secured in this experiment that urea nitrogen can be used to replace either 25 or 50 per cent of the nitrogen of a cottonseed meal supplement, when the net energy value of the supplement is maintained, without significantly affecting the digestibility of crude protein, ether-extract, crude fiber, nitrogen-free-extract, or organic dry matter in a steer fattening ration.

The biological utilization of urea nitrogen, up to a level of 50 per cent of the nitrogen of the supplement, was as efficient as the utilization of cottonseed meal nitrogen. The substitution of urea nitrogen for as much as 50 per cent of the supplemental nitrogen of cottonseed meal in a fattening ration for steers resulted in no observed ill effects and the amounts and physical character of urine and feces were normal.

LITERATURE CITED

Association of Official Agricultural Chemists. 1940. Official and Tentative Methods of Analyses, Ed. 5, 557 pp., illus. Washington, D. C.

Axelsson, J. 1942-43. The Value and Use of Urea in Animal Nutrition. (Abst). Nutrition Abstracts and Reviews, 12: 687.

x Bartlett, S., and A. G. Cotton. 1938. Urea as a Protein Substitute in the Diet of Young Cattle. J. Dairy Res., 9: 263-272.

x Briggs, H. M., W. D. Gallup, A. E. Darlow, D. F. Stephens, J. A. Hoefer, and W. D. Campbell. 1945. Urea as a Partial Protein (Nitrogen) Supplement for Beef Cattle. Okla. Exp. Sta. Mimeographed Circular 136: 27.

x Briggs, H. M., W. D. Gallup, A. E. Darlow, J. C. Hillier, C. E. Kinney, E. Harris, D. F. Stephens, J. A. Hoefer, and W. D. Campbell. 1946. Urea as a Partial Protein (Nitrogen) Supplement for Beef Cattle. Okla. Exp. Sta. Bul. 296: 24-28.

Fingerling, G., B. Hientzsch, H. Kunze, and K. Reifgerst. 1937. Ersatz des Nahrungeiweisses durch Harnstoff beim waschsenden. Rinde. Landw. Vers. Stat., 128: 221-235.

Hagemann, O. 1891. Landwirtsch. Jahrb., 20: 264.

x Harris, L. E., and H. H. Mitchell. 1941a. The Value of Urea in the Synthesis of Protein in the Paunch of the Ruminant. I. In Maintenance. J. Nutrition, 22: 167-182.

x Harris, L. E., and H. H. Mitchell. 1941b. The Value of Urea in the Synthesis of Protein in the Paunch of the Ruminant. II. In Growth. J. Nutrition, 22: 183-196.

x Hart, E. B., G. Bohstedt, H. J. Deobald, and M. I. Wegner. 1939. The Utilization of Simple Nitrogenous Compounds Such as Urea and Ammonium Bicarbonate by Growing Calves. J. Dairy Sci., 22: 785-798.

Henriques, V. and A. C. Anderson. 1914. Hoppe-Seyler's Ztschr., 92: 21.

x Johnson, B. C., T. S. Hamilton, H. H. Mitchell, and W. B. Robinson. 1942. The Relative Efficiency of Urea as a Protein Substitute in the Ration of Ruminants. J. Animal Sci., 1: 236-245.

Johnson, B. C., T. S. Hamilton, W. B. Robinson, and J. C. Garey. 1944. The Mechanism of Non-Protein Nitrogen Utilization by Ruminants. J. Animal Sci., 3: 287-298.

Lardinois, C. C., R. C. Mills, C. A. Elvehjem, and E. B. Hart. 1944. Rumen Synthesis of the Vitamin B Complex as Influenced by Ration Composition. J. Dairy Sci., 27: 579-583.

Loosli, J. K., and C. M. McCay. 1943. Utilization of Urea by Young Calves. J. Nutrition, 25: 197-202.

Maynard, Leonard A. 1937. Animal Nutrition. McGraw-Hill Book Co., Inc. New York and London, pp. 138-140.

Mills, R. C., A. N. Booth, G. Bohstedt, and E. B. Hart. 1942. The Utilization of Urea by Ruminants as Influenced by the Presence of Starch in the Ration. J. Dairy Sci., 25: 925-929.

Mills, R. C., C. C. Lardinois, I. W. Rupel, and E. B. Hart. 1944. Utilization of Urea and Growth of Heifer Calves with Corn Molasses or Cane Molasses as the Only Readily Available Carbohydrate in the Ration. J. Dairy Sci., 27: 571-578.

Morrison, F. B. 1945. Feeds and Feeding, A Handbook for the Student and Stockman. Ed. 20 Unabridged, 1050 pp., illus. Morrison Publishing Co., Ithaca, N. Y.

Muller, M. 1906. Pflugers Arch., 112: 245.

Murry, C. A., and A. E. Romyn. 1939. Urea as a Possible Substitute for Peanut Cake for Wintering Young Stock. Rhodesia Ag. J., 36: 554-559.

Oklahoma Agricultural Experiment Station. 1945. Unpublished Data.

Oklahoma Agricultural Experiment Station. 1946. Unpublished Data.

Owen, E. C., J. A. B. Smith, and N. C. Wright. 1943. Urea as a Partial Substitute in the Feeding of Dairy Cattle. Biochem. J., 37, 1: 44-53.

Pearson, R. M. and J. A. B. Smith. 1943. The Utilization of Urea in the Bovine Rumen. The Synthesis and Breakdown of Protein in Rumen Ingesta. Abst. J. Dairy Sci., 27: A45 or Biochem. J., 37, 1: 153-164.

Rupel, I. W., G. Bohstedt, and E. B. Hart. 1943. The Comparative Value of Urea and Linseed Meal for Milk Production. J. Dairy Sci., 26: 647-664.

Snedecor, George W. 1937. Statistical Methods Applied to Experiments in Agriculture and Biology. 341 pp., illus. Iowa State College Press, Ames, Iowa.

Wegner, M. I., A. N. Booth, G. Bohstedt, and E. B. Hart. 1941. The Utilization of Urea by Ruminants as Influenced by the Level of Protein in the Ration. J. Dairy Sci., 24: A162, Par. 339.

Zuntz, N. 1891. Pflugers Arch., 49: 483.

Typist:

Lucille Kinney