DIGESTION STUDIES WITH STEERS AND LAMBS

By

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Bachelor of Science, 1947

Master of Science, 1948

University of Kentucky

Lexington, Kentucky

Submitted to the Faculty of the Graduate School of

the Oklahoma Agricultural and Mechanical College

in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

1951

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ACKNOWLEDGMENT

The writer wishes to express his appreciation to Doctor C. K. Whitehair, Professor of Animal Husbandry, for his suggestions in planning and initiating these studies. The helpful suggestions of Doctor A. E. Darlow, Head of the Animal Husbandry Department, are also deeply appreciated.

He also wishes to thank Doctor W. D. Gallup, of the Department of Agricultural Chemistry, for help in the chemical analyses and for his many excellent suggestions.

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INTRODUCTION

Digestion studies have furnished fundamental information pertaining to feed requirements of various animals. In the ruminant, the microorganisms in the gastrointestinal tract are responsible for carrying out a large part of the digestive processes for the host. These microorganisms have preference as to the type of compounds which they will attack and digest. Certain forms of inorganic nitrogen can be utilized by these microorganisms to build their own cellular protein which in turn becomes available to the host as protein.

A minimum of protein is required for normal body processes, and a deficiency of protein may be expected to result in economic losses to the livestock producer. In the past, there have been shortages of natural forms of protein supplements for livestock.

Urea has been used as a protein substitute in rations for cattle and sheep. It is a commercially produced, white, crystalline nitrogenous compound which contains 262 percent crude protein equivalent. Since urea can be economically produced in large quantities, it would help relieve protein shortages if it is a safe feed and if it can be efficiently utilized with various feeds.

Since ruminants are primarily roughage consuming animals and roughages are economical sources of energy, it was desirable to learn more about roughage utilization by ruminants. Some substances have been shown to improve roughage utilization while others have been shown to depress it.

This investigation was designed to determine the effect of various carbohydrate feeds on the utilization of urea nitrogen; the effect of feeding high levels of urea; the effect of sucrose, glucose and lactose on digestion; and the effect of an antibiotic, aureomycin, on digestion.

LITERATURE REVIEW

The literature review included in this thesis is concerned primarily with the results of experiments using urea in nitrogen balance studies with some reference to the use of urea in feed lot trials. Limited reference material was available as to the effect of simple carbohydrates and of antibiotics on digestion.

Armsby (1911) reviewed the literature on protein synthesis from non-protein nitrogen by ruminants, and concluded that ruminants were able to utilize non-protein nitrogen only to a limited extent.

Hart *et al*., (1939) at the Wisconsin Station started the first intensive research in the United States on the nutritional value of urea. They obtained good results on growing calves with urea furnishing 43 percent of the nitrogen in rations consisting of corn starch and timothy hay. In further work at Wisconsin, Mills *et al*., (1942), (1944) used the rumen fistula technique to demonstrate that corn starch greatly increased the utilization of urea nitrogen.

Urea Metabolism Studies

Dinning (1948) at the Oklahoma Station found that urea significantly increased nitrogen retention in both steers and lambs. Urea significantly increased the apparent digestibility of crude protein for steers and lambs but did not affect the digestibility of other ration nutrients. In a later report, Dinning *et al*., (1949) found that for lambs and steers, pellets containing 50 percent of the nitrogen as urea were utilized as efficiently in metabolism studies as pellets containing 25 percent of the nitrogen as urea. However, there were feed refusals by steers when 50 percent pellets were fed in some of the rations.

In Canada, Watson and associates, (1949a), (1949b), using 30 beef calves and 60 lambs, demonstrated that urea, when added to a ration very low in protein, was an adequate protein substitute but not as good as casein. Urea increased the production of meat in steers and wool in lambs. They further demonstrated that nitrogen from N^{15} labelled urea was used by sheep to make tissue protein. N^{15} was found in excess of the normal amount in proteins separated from liver, blood and kidneys.

Clark and Quinn (1951) in South Africa found that the supplementation of poor quality grass hay with either urea or sodium nitrate in conjunction with molasses increased the appetite and helped maintain body weight in lambs. Ammonium nitrate and ammonium sulfate gave no beneficial effect when fed at levels supplying the same nitrogen intake as the urea supplementation.

Glasscock et al., (1950) at the Florida Station reported that urea added to a wintering steer ration composed of prairie hay and citrus molasses reduced the loss of weight when the intake of feed was limited. When hay was fed free choice, the steers fed urea in addition to molasses and hay gained 0.75 lb. daily while the controls lost 0.60 lb. daily. Urea supplementation increased the appetite of the steers.

Culbertson et al., (1951) reported that the substitution of 0.2 lb of urea for 1.25 lb. of soybean meal in rations for fattening steers, gave better results than the soybean meal. They reported that the addition of a small amount of molasses to the urea ration or to the soybean meal ration was not beneficial in any respect. The rations to which they added urea and soybean meal were not low in protein and no "negative" controls were used.

Urea has been recommended to be fed at a level of not over 1 percent of the ration or not over 3 percent of the concentrate mixture. However, Loosli et al., (1949) fed a purified diet to lambs and goats, and found that urea could satisfactorily supply all of the nitrogen for these animals. Traces of nitrogen were found in some of the purified feeds. Urea was fed as 4 percent of the ration to lambs which gained 0.23 lb. daily as compared to 0.30 lb. for lambs fed casein.

Bowstead and Fredeen (1948) reported that urea fed to dairy cows at a level above 0.5 percent of the ration was unpalatable to some of the cows. Molasses added to the urea rations increased the palatability.

Burroughs and coworkers, (1951a) at the Ohio Station found that the nitrogenous requirements of rumen microorganisms are relatively simple and that they require essentially ammonia and not amino acids. They further postulated that rumen microorganisms have three general requirements, namely: energy, nitrogenous substances and inorganic constituents that are involved in enzymes or enzyme systems. In discussing the effect of protein on urea utilization, they pointed out that a protein may enter into direct competition with urea in supplying ammonia to the microorganisms if the protein level is high. Hence, a low protein intake gives the best utilization of urea. Proteins containing minerals needed by microorganisms may also enhance the utilization of urea.

McDonald and Baldwin (1948) stated that ammonia disappears from the rumen; (1) by use for bacterial growth; (2) by passage from the rumen into the abomasum; and (3) by absorption.

McDonald (1948) demonstrated that the parotid gland of sheep normally secretes urea when sheep are on normal rations. Therefore, the utilization of urea in the paunch of ruminants is a normal function. He found that sheep on normal rations had much higher ammonia concentrations in the portal blood draining the rumen than that of the systemic circulation.

Arias and associates (1951) at the Ohio Station suggested that since roughages are low in readily available carbohydrates, the energy content of a protein may aid cellulose digestion directly, and indirectly, aid urea utilization. They stated that rumen microorganisms need a small amount of readily available carbohydrate for the most efficient utilization of urea when the principle source of energy is cellulose. They further suggested that the feeding of large amounts of readily available carbohydrates seems unwarranted in promoting maximum urea utilization. In these *in vitro* studies, the Ohio workers found that by increasing the energy content of the fermentation media the urea utilization by rumen microorganisms was increased. This was independent of the type of energy as an increase in urea utilization was obtained by adding dextrose, sucrose, molasses, starch, cellulose, or corn cobs. They found that cellulose digestion decreased about 24 percent when each of these energy sources was added except when molasses or cellulose was added. The percentage of digested cellulose remained about the same even when the amount of molasses or cellulose was increased.

Burroughs *et al*., (1951b) found that cane molasses stimulated urea utilization due to its sugar and ash content. The addition of molasses, molasses ash, or sugar plus molasses ash significantly increased cellulose digestion while sugar alone did not. By increasing the starch content of the media, they found that the requirements of ash increased for the most efficient digestion of cellulose and for the most efficient utilization of urea. They also found that equivalent amounts of ash from high quality clover hay or low quality timothy hay gave results comparable to molasses ash. Using iron, phosphorus, magnesium, potassium, and calcium, they found that only iron increased urea utilization in these *in vitro* studies.

The Feeding of High Levels of Urea

Hart et al., (1939) reported kidney damage in dairy calves fed a ration containing 2.8 percent and 4.3 percent urea (dry weight basis) over a long period of time. Work et al., (1943) found no liver or kidney damage from feeding urea to cattle at the rate of 2.29 percent of the dry matter consumed. Dinning et al., (1948) demonstrated the toxicity of urea by administering urea by means of a stomach tube. Dosages of 116 gm. or larger given in this manner to 500 pound steers resulted in symptoms characteristic of alkalosis followed by death. Within 20 minutes after the administration of urea, the steers showed ataxia which became progressively worse until the steers were unable to stand and went into severe tetany. Respiration became slow with frequent gasping and frothing at the mouth followed by death. As the toxicity progressed, there was a rapid rise in blood ammonia accompanied by a rise in blood urea. By gradually increasing the urea in the ration, a 2-year old steer was induced to eat 400 gm. of urea daily for seventy days. No kidney or liver damage was noted when the steer was slaughtered. The urea was fed in a mixture of conttonseed meal, hominy feed, molasses and prairie hay.

Hoflund et al., (1948) reported symptoms characteristic of alkalosis followed by death in one of two sheep changed from a poor protein ration to a ration of alfalfa leaves and casein. The rumen contents of this sheep smelled strongly of ammonia. This fatality appeared after the sheep had consumed one kilogram of alfalfa leaves and 100 grams of casein daily for four days. The other sheep showed no ill effects except for a drop in cellulose digestion.

Briggs et al., (1947a) found no ill effects from feeding 0.37 lb. of urea daily to 450 lb. steers for 14 days. This amount of urea was about 2.2 percent of the dry matter consumed. The kidneys of all steers appeared normal when the steers were slaughtered. New York Toxicology Reports (1950) from several feed control laboratories indicated that toxic results were being encountered under practical feeding conditions. The toxic results were due to the feeding of high levels of urea which was apparently due to errors in the process of mixing feed ingredients.

Clark and associates, (1951) reported toxic results in sheep from introducing urea directly into the rumen by means of a hypodermic needle and by rumen fistula. They observed a reduction in rumen motility in addition to the characteristic symptoms described earlier by Dinning et al., (1948). Post mortem examination showed severe fatty degeneration of the kidney and liver with hemorrhages in the heart and splanchnic area. In some animals severe pulmonary congestion and edema was noted. They observed toxic results in sheep which were on a poor ration of grass hay then dosed with 24 gm. urea per 100 lb. of body weight. Toxicity was increased by introducing base and decreased by introducing an acid into the rumen. The dosing of 18 gm. of urea per 100 lb. of body weight on a poor ration of grass hay reduced the appetite of lambs, but gave no other ill effects. The same dosage to sheep starved for 72 hours resulted in death in 4 out of 6 cases. They stated that sucrose gave some protective action against urea toxicity but their data does not appear to support this statement. A high protein intake of casein, or alfalfa hay gave a protective action against urea toxicity even at levels of 36 gm. of urea per 100 pounds of body weight. Injection of ammonium hydroxide solutions intravenously, produced a toxicity but there were no tetanic convulsions or fatalities. Injection of acetic acid into the rumen or intravenously reduced the urea toxicity, and intravenous injection of 20 gm. of urea produced no ill effects. They suggested that the toxicity resulting from the administration of urea into the rumen may be due to the formation of toxic intermediary products of ammonia.

Weil-Malherbe (1950) suggested that the toxicity of blood ammonia is not due to an upset of the acid-base balance of the blood but to a specific ammonia toxicity. He stated that the amount of ammonia required to give toxic symptoms is too small to upset the acid-base balance in the blood.

Digestion Studies with Simple Carbohydrates

Swift et al., (1947) reported that the addition of straw, starch, cerelose, casein and corn oil decreased the digestibility of crude fiber for ruminants. Cerelose (glucose) had the least effect on crude fiber digestibility.

Hamilton (1942) reported that glucose added to lamb fattening rations, decreased the digestibility of crude protein and crude fiber.

Colovos et al., (1949) compared the effect of adding wood molasses and cane molasses to rations of hay alone. Wood molasses which consisted primarily of glucose, decreased the apparent digestibility of crude protein to a greater extent than cane molasses which consisted primarily of sucrose.

Hungate (1950) studied various types of bacteria and found that certain types of these bacteria would only attack cellulose or starch and their hydrolysis products. Other types would ferment sucrose, lactose, galactose, fructose and/or cellulose.

EXPERIMENTAL OBJECTIVES

Experiments were designed to answer the following questions:

Part I The utilization by steers of urea nitrogen in rations containing different carbohydrate feeds;

Part II The feeding of high levels of urea;

Part III The utilization of sucrose, glucose, and lactose by lambs; and

Part IV The effect of aureomycin on digestion in steers.

PART I

UTILIZATION BY STEERS OF UREA NITROGEN IN RATIONS CONTAINING DIFFERENT CARBOHYDRATE FEEDS

In areas outside of the cornbelt, it is sometimes more economical and desirable to feed other grain or grain substitutes in place of corn for beef production. Urea has been shown to be of value as a source of nitrogen for ruminants when added to low protein rations containing corn. Sweet potatoes, barley, milo and cane molasses have been found to be good substitutes for corn in beef cattle rations. In three metabolism experiments, the effect of adding urea to these carbohydrate feeds was studied.

Experimental Procedure

Grade Hereford steers were used in these metabolism studies. Yearling steers averaging about 650 pounds were used in the first metabolism study while weanling steer calves weighing about 500 pounds were used in the second and third metabolism studies. They were kept in metabolism stalls with a standard 10-day preliminary period preceding each 10-day collection period. In each study, the steers were rotated so that each steer was on each ration during preliminary and collection periods. The steers were fed and watered twice daily. Due to the abnormal surroundings of the steers in the metabolism stalls, it was difficult to get the feed consumption to a desirable level. The level of feeding was determined by the intake of the steer which consumed the least amount of feed.

Feces were collected in gutter boxes and removed at frequent intervals and placed in covered containers. The feces were weighed daily, aliquoted and the samples preserved with thymol and refrigeration. After drying the samples, proximate analyses as described by the Association of Official Agricultural Chemists (1940), were made on the composite samples. Urine was collected by means of a rubber funnel supported by two straps over the back of each steer. A hose connected to the funnel directed the urine through the false bottom stalls into 8 liter collection bottles. The urine was measured daily and an aliquot, acidified with concentrated HCl was stored in the refrigerator. Total urinary nitrogen was determined by the Kjeldahl method on the composite 10-day samples from each steer.

In the calculation of biological values the Thomas-Mitchell formula was used.

Biological value =

$$\frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$$

The metabolic nitrogen and endogenous nitrogen were determined according to Swanson and Herman (1943). Metabolic nitrogen was considered to be 5.3 grams per kilogram of dry matter consumed. The endogenous urinary nitrogen was calculated on the basis of the average body weight of the steers using the formula; $N = 0.712\ W^{0.42}$ (W = body weight in kilograms). The values used for metabolic nitrogen and endogenous nitrogen were obtained by Swanson and Herman from the feeding of rations low in nitrogen.

The hay used in these experiments was average quality prairie hay obtained in the vicinity of Stillwater, Oklahoma. The corn used was number 2 yellow corn which was coarsely ground. The horticulture department of Oklahoma Agricultural and Mechanical College furnished the dehydrated sweet potatoes. The sweet potatoes were shredded and dried in a commercial type of dehydrator. The barley used was common, rolled barley. The milo used was coarsely ground and the cane molasses was New Orleans blackstrap. Analysis of feeds are given with the results of each experiment. The data in the results of each experiment were statistically analyzed according to Snedecor (1946).

Results of the Corn and Sweet Potato Metabolism Study

The rations fed and the chemical composition of the feeds used in this study are given in Table 1. The average chemical compositions of each ration is given in Table 2. The dry matter content was approximately the same in all rations. The crude protein content was the same in rations A and C which consisted of the corn and sweet potato rations respectively. Rations B and D which were supplemented with urea had the same crude protein content.

The average daily nitrogen balance and biological value data are given in Table 3. The addition of urea in ration B increased the nitrogen retention over ration A from 6.3 grams to 17.4 grams. This difference was statistically significant (P = .01) when tested by the t-test of Snedecor (1946). The addition of urea in ration D significantly increased the nitrogen retention when compared with the nitrogen retention on ration C. There were no significant differences between the nitrogen retention by steers on the rations which had the same nitrogen content.

The average biological values were significantly higher for the rations containing sweet potatoes than for the rations containing corn. This shows that the steers were able to utilize the digested nitrogen more efficiently in the rations containing sweet potatoes than in the rations containing corn. However, the actual amount of nitrogen digested was less in the rations containing sweet potatoes than in the corn rations.

The average apparent digestion coefficients for this metabolism study are given in Table 4. The only observed effect of urea was to significantly increase the digestibility of crude protein. The average dry matter digestibility in ration B (corn + urea) was significantly higher than that of ration D (sweet potatoes + urea). Other differences in dry matter digestion coefficients among rations were not statistically significant. The addition of urea significantly increased the digestibility of crude protein in the corn and sweet potato rations. The corn rations had significantly higher crude protein digestion coefficients than the sweet potato rations. There were differences in the digestibility of ether extract, however, the ether extract intake was lower for the sweet potato rations. The corn rations had higher coefficients of digestibility of crude fiber which were statistically significant. There were no significant differences in the digestibility of NFE (nitrogen free extract) among the four rations.

TABLE 1

Daily Amounts and Chemical Composition of the Feeds Used in the Corn and Sweet Potato Metabolism Study

Feed	Daily Allowance in Ration				Dry Matter	Percentage Composition of Dry Matter				
	A	B	C	D		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
	gm.	gm.	gm.	gm.	percent					
Prairie Hay	2,000	2,000	2,000	2,000	90.50	93.17	4.20	2.15	34.65	52.16
Yellow Corn	3,000	3,000			87.78	98.54	9.36	4.68	2.12	82.38
Sweet Potatoes			2,600	2,600	93.22	94.69	6.58	0.86	3.98	83.27
Cottonseed Meal			228	228	92.02	94.46	41.44	6.67	12.36	33.99
Salt	30	30	30	30	100.00					
Bonemeal	44	44	44	44	96.52	18.75				
Urea "262" *		50		50	100.00	98.14	262.00			

* Urea in the form of "Two-Sixty-Two" feed compound was supplied by E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware.

TABLE 2

Chemical Composition of the Rations Fed Steers in the Corn and Sweet Potato Metabolism Study

Ration	Percentage Composition of Dry Matter				
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	94.99	7.14	5.81	15.13	68.95
B	95.03	9.93	5.74	14.96	68.20
C	92.54	7.14	1.63	16.60	67.18
D	92.60	9.93	1.62	16.42	66.45

TABLE 3

Average Daily Nitrogen Balance and Biological Value Data of the Corn and Sweet Potato Metabolism Study

Ration	Trials	Intake		Excretion		N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
		Dry Matter	N	Fecal N	Urinary N						
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
A	5	4511	51.7	25.9	19.5	6.3	23.9	8.1	49.8	38.3	77.1
B	6	4552	72.5	25.7	29.4	17.4	24.1	8.1	71.0	49.3	69.5
C	9	4420	51.2	31.1	14.5	5.6	23.4	8.2	43.5	37.2	85.4
D	8	4419	72.8	34.5	22.3	16.0	23.4	8.1	61.7	47.6	77.2

TABLE 4

The Average Apparent Digestion Coefficients of the Corn and Sweet Potato Metabolism Study

Ration	Trials	Apparent Percentage of Digestibility					
		Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	5	67.3	69.2	49.9	68.2	62.6	72.8
B	6	71.5	73.8	64.5	76.2	66.8	77.3
C	9	66.0	68.1	39.7	53.8	50.2	76.3
D	8	67.2	69.5	52.6	58.7	51.2	77.9

Results of the Corn, Barley and Milo Metabolism Study

The chemical composition of the feeds used in this study are given in Table 5. The rations fed the steers are given in Table 6 and the chemical composition of these rations are given in Table 7. The total dry matter of each ration was approximately the same. The crude protein content in each ration not supplemented with urea was approximately the same. The same amount of urea was added to each of the carbohydrate concentrates in rations B, D, and F to provide an equivalent crude protein content of these three rations. Ration G had a sufficient amount of soybean meal substituted for part of the barley to give the same dry matter content and the same crude protein content as the urea supplemented rations. Ration G was fed after the major part of the study was completed.

The average daily nitrogen balance and biological value data are given in Table 8. The addition of urea significantly ($P = .01$) increased the nitrogen retention by steers in the rations to which it was added. There were no significant differences in the nitrogen balances among the rations in which the nitrogen content was equal. A comparison of the average biological value of the nitrogen among the rations of equal nitrogen content demonstrated no statistically significant differences.

The average apparent digestion coefficients for this metabolism study are given in Table 9. The only effect of urea on digestion was that it significantly increased the digestibility of crude protein in every ration to which it was added. The crude protein digestibility of the corn and barley rations was significantly higher than the crude protein digestibility of the milo rations. The differences in dry matter digestion coefficients among the rations were not statistically significant. The digestibility of ether extract in the barley rations was less than the digestibility in either the corn or the milo rations, however the ether extract content of the barley rations was lower than that of the other rations. The apparent digestibility of the crude fiber in the barley rations was significantly lower than the apparent digestibility of crude fiber in the corn and milo rations, however there was very little difference in the total amount of crude fiber digested regardless of the ration. Differences in the digestibility of NFE among the rations were not statistically significant.

TABLE 5

Average Chemical Composition of Feeds used in the Corn, Barley and Milo Metabolism Study

Ingredient	Dry Matter (Percent)	Percentage Composition of Dry Matter				
		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
Prairie Hay	92.53	92.85	4.70	2.38	34.59	51.18
Corn	89.67	98.17	10.76	3.96	2.10	81.35
Barley	89.89	96.95	12.09	1.89	5.54	77.43
Milo	89.36	98.51	10.73	3.84	1.69	82.25
Soybean Meal	92.19	92.16	47.36	6.18	6.03	32.49
Bonemeal	97.75	10.69	5.91	.24	2.90	1.64
Salt	100.00					
Urea "262"	100.00	100.00	262.00			

TABLE 6

Daily Allowances in Grams of Rations in the Corn, Barley and Milo Metabolism Study

Ingredient	A	B	C	D	E	F	G
Prairie Hay	1800	1800	1800	1800	1800	1800	1800
Corn	1730	1730					
Barley			1800	1800			1486
Milo					1736	1736	
Soybean Meal	70	70			64	64	354
Bonemeal	50	50	50	50	50	50	50
Salt	30	30	30	30	30	30	30
Urea "262"		45		45		45	

TABLE 7

Chemical Composition of the Rations Fed in the Corn, Barley and Milo Metabolism Study

Ration	Percentage Composition of Dry Matter				
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	93.27	8.29	3.13	18.27	63.57
B	93.35	11.65	3.09	18.03	62.73
C	92.80	8.23	2.09	19.84	62.63
D	92.89	11.58	2.06	19.58	61.81
E	93.51	8.22	3.07	18.10	64.04
F	93.51	11.56	3.03	17.86	63.19
G	91.85	11.60	2.49	19.59	58.18

TABLE 8

Average Daily Nitrogen Balance and Biological Value Data of the Corn, Barley and Milo Metabolism Study

Ration	Trials	Intake: Dry Matter	Intake: N	Excretion: Fecal N	Excretion: Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
A	6	3366	44.4	23.4	14.1	6.9	17.8	7.3	38.8	32.0	82.5
B	6	3414	63.3	24.3	27.4	11.6	18.1	7.2	56.8	36.6	64.4
C	6	3357	43.9	21.3	15.7	6.9	17.8	7.2	40.3	31.8	79.1
D	6	3405	62.9	21.5	30.3	11.1	18.1	7.2	59.4	36.3	61.2
E	6	3362	44.1	26.5	13.1	4.6	17.8	7.3	35.5	29.7	83.6
F	6	3394	63.0	26.6	25.9	10.5	18.0	7.3	54.4	35.8	65.8
G	6	3383	63.7	21.1	29.8	12.8	17.9	7.3	60.5	38.1	62.9

TABLE 9

Average Apparent Digestion Coefficients of the Corn, Barley and Milo Metabolism Study

Ration	Trials	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	6	64.3	66.1	47.2	64.9	65.7	68.7
B	6	64.6	65.9	61.6	66.6	66.2	68.3
C	6	62.8	64.9	51.5	48.3	60.0	68.6
D	6	62.9	64.6	65.7	49.9	59.9	68.3
E	6	62.4	64.4	39.9	65.0	64.6	67.6
F	6	64.6	66.1	57.8	61.7	64.3	70.2
G	6	67.6	69.8	66.9	61.2	63.6	72.5

Results of the Corn and Molasses Metabolism Study

The chemical composition of the feeds used in this study is given in Table 10 and the rations fed the steers are given in Table 11. Table 12 shows the average chemical composition of each ration fed to the steers.

The average nitrogen balance and biological value data for this study are presented in Table 13. Nitrogen balances were significantly increased by the addition of urea to each of the rations, however, there were no significant differences in nitrogen retention by steers on the rations which had the same nitrogen content. The biological value of the nitrogen in the corn ration containing urea (ration B) was significantly higher than the biological value of the nitrogen in the two rations containing molasses and urea. There were no statistically significant differences in the biological values among the rations which did not contain urea.

The average apparent digestion coefficients for the rations tested in this study are given in Table 14. The only effect of urea was to significantly increase the digestibility of crude protein in these rations. In the urea supplemented ration consisting of corn and molasses as the carbohydrate feed, the average dry matter digestibility was greater than in the urea supplemented rations consisting of corn or molasses alone. The rations containing corn had significantly higher digestion coefficients for crude protein than rations containing molasses. Digestion coefficients of crude protein for rations containing corn and molasses were not significantly different from the corn rations or the molasses rations. The crude fiber digestion coefficients were lower for the rations which consisted of molasses without corn, however these differences were not statistically significant. Rations containing corn and molasses supplemented with urea had a significantly higher digestibility of NFE than the urea supplemented rations containing corn alone.

Due to differences in the intake of ether extract, the differences in the apparent digestibility of ether extract were not compared.

TABLE 10

Average Chemical Composition of Feeds Used in the Corn and Molasses Metabolism Study

Ingredient	Dry Matter (Percent)	Percentage Composition of Dry Matter: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
Prairie Hay	92.69	92.63	5.04	2.07	35.74	49.78
Corn	88.36	98.45	10.42	4.49	2.32	81.24
Molasses	69.13	87.98	3.99			83.99
Soybean Meal	91.16	93.55	48.26	5.62	5.54	34.13
Bonemeal	95.53	9.77	4.39			5.38
Salt	100.00					
Urea "262"			262.00			

TABLE 11

Daily Allowances of Feeds in Grams Used in the Corn and Molasses Metabolism Study

Ingredient	A	B	C	D	E	F
Prairie Hay	1800	1800	1800	1800	1800	1800
Corn	1710	1710	854	854		
Molasses			836	836	1670	1670
Soybean Meal	90	90	224	224	356	356
Bonemeal	50	50	50	50	50	50
Salt	30	30	30	30	30	30
Urea "262"		45		45		45

TABLE 12

Average Composition of Rations Fed in the Corn and Molasses Metabolism Study

Ration	Percentage Composition of Dry Matter				
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	93.26	8.50	3.21	19.04	62.49
B	93.35	11.84	3.16	18.79	59.56
C	91.15	8.72	2.43	19.04	60.95
D	91.27	12.15	2.40	18.79	57.93
E	88.96	8.95	1.64	19.05	59.33
F	89.11	12.44	1.61	18.78	56.29

TABLE 13

Average Daily Nitrogen Balance and Biological Value Data of the Corn and Molasses Metabolism Study

Ration	Trials	Intake		Excretion		N Bal-ance	Meta-bolic N	Endog-enous N	True Digested N	Absorbed N Utilized	% Bio-logical Value
		Dry Matter	N	Fecal N	Urinary N						
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	
A	5	3338	45.2	20.1	12.9	12.2	17.7	7.4	42.8	37.3	87.3
B	6	3388	64.2	20.8	25.5	17.9	18.0	7.4	61.3	43.2	70.5
C	6	3285	45.9	22.6	13.1	10.2	17.4	7.5	40.7	35.3	86.6
D	6	3333	64.7	22.2	28.1	14.4	17.7	7.5	60.2	39.4	65.5
E	6	3230	46.3	24.0	13.8	8.5	17.2	7.5	39.4	33.1	83.9
F	6	3264	64.9	24.1	27.5	13.3	17.3	7.5	58.1	38.1	65.5

TABLE 14

Average Apparent Coefficients of Digestion for the Corn and Molasses Metabolism Study

Ration	Trials	Apparent Percentage of Digestibility					
		Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	5	69.3	71.2	55.5	70.7	69.5	73.8
B	6	68.1	69.9	67.2	71.1	69.6	70.4
C	6	69.6	71.6	50.9	65.5	69.2	75.6
D	6	70.5	72.2	65.6	66.2	69.8	75.0
E	6	68.2	69.9	48.1	49.8	67.4	74.6
F	6	68.3	70.2	62.9	48.6	67.2	73.4

Discussion (Part I)

Urea significantly increased the nitrogen retention by steers regardless of the carbohydrate feed to which it was added. The greatest increase in nitrogen retention was in the first metabolism study where these rations consisted of 60 percent concentrates and 40 percent roughage with a crude protein content of 7 percent. The rations fed to the steers in the second and third metabolism studies consisted of 50 percent concentrates and 50 percent roughage with a crude protein content above 8 percent. The steers used in the first metabolism study were older than those used in the second and third metabolism studies. A higher percentage of crude protein was included in the rations of steers in the second and third experiment because younger steers have higher protein requirements than older steers. The steers used in the corn and sweet potato metabolism study also had a higher intake of energy in proportion to their body weight than the other steers. As a result they were able to get a greater increase in nitrogen retention from the added nitrogen of urea. Thus, a direct comparison of the results among the three metabolism studies is not justified since, as previously mentioned, the animals and rations were different and also the experiments were not conducted at the same time.

A positive nitrogen balance is an indication of growth, therefore, the steers on the urea supplemented rations grew more than when they were on the unsupplemented rations. The feed intake was not high enough for the steers to make normal growth but they made a small amount of growth which was indicated by the positive nitrogen balance values.

Urea did not significantly affect the excretion of fecal nitrogen in any of the studies. Since urea is a readily soluble compound and is broken down to ammonia by the enzyme urease in the paunch of ruminants, it would be expected to be highly digested due to ammonia absorption and bacterial utilization of ammonia.

Urea significantly increased the apparent digestibility of crude protein in every case. It had no apparent effect on the digestibility of other ration nutrients. Urea has been shown to increase the digestibility of dry matter when added to a ration low in crude protein but it has not been shown to affect the dry matter digestibility of rations comparable to those used in these studies.

There were differences in the digestibility of nutrients among the various carbohydrate feeds. In the corn and sweet potato study, the dry matter digestibility of the corn and urea ration was significantly higher than for the sweet potato and urea ration. There was some indication of charring of the sweet potatoes in the dehydration process which may have lowered the digestibility of crude protein in the sweet potato rations. These results confirm those obtained by Briggs et al., (1947). This also confirms the reports that dehydrated sweet potatoes are worth from 85 percent to 95 percent as much as corn as a carbohydrate feed.

In the corn and sweet potato metabolism study, there was a higher percentage of crude fiber digested in the corn ration than in the sweet potato rations. The sweet potato rations contained more crude fiber than the corn rations but the total crude fiber digested was greater in the corn rations. This is in contrast to the results obtained by Briggs et al., (1947) who found no difference in the percentage of digestibility of crude fiber of corn rations and sweet potato rations comparable to those fed in this study. The sweet potatoes which they used were shredded and sun dried instead of mechanically dehydrated.

In the corn, barley and milo metabolism study, there were small differences in the digestibility of nutrients among the three carbohydrate feeds. Morrison (1948) stated that barley and milo are worth almost as much as corn for fattening cattle.

In the corn and molasses metabolism study, the cane molasses contained more protein and less dry matter than was anticipated. This resulted in a higher intake of crude protein and a lower intake of dry matter in the rations containing molasses than in the corn rations. It was thought that cane molasses, a readily soluble carbohydrate feed, would enhance the value of urea nitrogen. In this study, the addition of urea to the molasses ration with no corn, significantly increased the nitrogen retention (P = .05), while the increased retention of nitrogen when urea was added to each of the other carbohydrate feeds was highly significant (P = .01). As the amount of molasses in the rations increased, the crude protein digestibility decreased and the nitrogen retention was lowered. Morrison (1948) indicates that there is no digestible protein in cane molasses, therefore the crude protein digestibility would be expected to be lower when corn is replaced with molasses and soybean meal.

The urea supplemented ration, in which one half of the corn was substituted with cane molasses, had a significantly higher dry matter digestibility than either of the other urea supplemented rations containing corn or the one containing molasses. Differences were small in dry matter digestibility among these rations, but statistically, these results show that in urea supplemented rations, a combination of corn and molasses is superior to either corn or molasses alone as a carbohydrate feed for steers.

Burroughs et al., (1951) reported that cane molasses stimulated urea utilization due to its sugar and ash content. Arias and associates (1951) stated that in vitro studies showed that the energy in the fermentation media increased urea utilization by rumen microorganisms. This was independent of the type of energy as an increase in urea utilization was obtained from the addition of either dextrose, sucrose, molasses, starch, cellulose, or corn cobs.

No comparisons were made of the digestibility of ether extract among the various rations. The intakes of ether extract were variable, while there were small differences in the excretion of ether extract regardless of the ration.

PART II

THE FEEDING OF HIGH LEVELS OF UREA

It has been demonstrated that force feeding of urea to steers in large amounts results in fatalities. Prior to this study, no experimental evidence was available which demonstrated that urea would be voluntarily consumed in sufficient quantities to give fatal results. Several workers have suggested that molasses would give a protective action against toxicity in ruminants resulting from ingesting urea. Experiments in the feeding of high levels of urea in molasses mixtures were carried out. The use of various antidotes in treating urea toxicity were also tested.

Experimental Procedure

Seven grade steers and one heifer weighing from 245 lb. to 500 lbs.were used in the first series of tests. Four of the steers were individually fed twice daily four different combinations of molasses and urea while the other steer was used as a control. During the first week, the four steers consumed 4 lbs. of a molasses-urea mixture and 6 lbs. of prairie hay. The next week the steers were fed 8 lbs. of the molasses-urea mixtures. The fifth steer was fed corn, hay and conttonseed meal during these two weeks. During the next 18 days, 2 of the steers were continued on a full feed of molasses-urea plus 6 lbs. of hay. Two steers were drenched with urea and the control steer was fed molasses free choice, prairie hay and cottonseed meal. Frequent observations were made to determine if any toxic symptoms were present.

The two steers drenched with urea were treated in an attempt to relieve the toxicity. The control steer consumed a toxic dose of molasses-urea after a 48 hour fast. Blood values for urea, ammonia, and sugar were determined for all steers throughout the experiment. Blood urea was determined colorimetrically by the method of Archibald (1945). Blood ammonia was determined by a variation of the Van Slyke, and Cullen (1914) aeriation procedure. The Folin Wu method of colorimetric determination of reducing sugars as described by Hawk et al., (1947) was used for blood glucose determinations.

Solutions of glutamic acid, dextrose, calcium gluconate, and chloral hydrate were used for therapy.

In an additional study two steers (245 lbs., 345 lbs.) and one heifer (330 lbs.) were used in an attempt to induce them to consume sufficient urea in a salt mix and in a molasses-urea mix to give toxic symptoms. One of the steers was drenched with molasses-urea. Solutions of thiadex and nembutal were given intravenously as treatment. Dilute acetic acid was also injected into the rumen as an antidote.

Results and Discussion

The rations fed to the steers and the results of the first part of the urea feeding study are given in Tables 15 and 16. During the first seven days of this experiment each of the four steers consumed 4 lbs. of the molasses-urea mixtures. The steers fed the more concentrated urea in molasses were slower to consume the feed than the other steers. During the seven days, blood ammonia and blood urea increased in all steers fed urea while the blood sugar was approximately the same as the blood sugar of the control steer. If molasses is absorbed as reducing sugars the systemic blood sugar would be expected to increase unless the liver is able to keep the reducing sugar content of the systemic blood rather constant. There was very little change in the blood urea or blood ammonia in the control steer during the first seven days, and it was much lower that that for the urea fed steers. Rankin (1942) obtained a rise in systemic blood reducing sugar by placing dextrose into the rumen by means of a rumen fistula. The percentage of increase in blood sugar was from 34 percent to 400 percent. When he placed a smaller amount of dextrose (4 gm. dextrose/kg. body weight) into the rumen, he obtained no increase in blood sugar. Krymanek and Briggemann (1933) found that glucose given by stomach tube to sheep had no effect on the reducing sugars in the systemic circulation, while the same amount given by fumen fistula gave a substantial increase in blood sugar. They attributed this difference to the unjury from the rumen fistula which upset the normal rumen function.

During the second seven days of this study eight lbs. of the molasses-urea mixtures was fed daily. Feed refusals of approximately 1 lb. of molasses-urea mixture were encountered with steers 3 and 4 which were fed the higher concentrations of urea. During these seven days the blood urea was higher than during the previous seven days for all the steers fed urea. The blood sugar and blood ammonia values were about the same as the values obtained during the previous seven days. One exception was steer 4 which exhibited higher blood ammonia levels than the others. It was difficult to measure blood ammonia at the low concentrations encountered even with the use of 0.01 normal acid and base. Small errors in titration may account for the fluctuation obtained in the blood ammonia values. The control steer had normal values for all the blood constituents which were measured during these seven days.

During the third seven day period Du Pont's urea reaction products A and B were poured over the hay for the steers, but the steers refused most of the reaction products. These products had a burnt-sugar, caramelized taste. The chemical composition of these products was:

	Product A	Product B
% Crude protein equivalent	86	110
% Nitrogen	13.7	17.7
% Unreacted urea	19.5	28.9

During the next 18 days, steers 1 and 2 were fed 8 lbs. of 6:1 and 5:1 molasses-urea mixtures respectively. Feed refusals were about the same as that of steers 3 and 4 when these steers were given the same amounts of molasses-urea mixtures. Blood urea values were higher for steers 1 and 2 during this 18 day period than any of the blood values observed previously. Blood ammonia values were within the range observed for urea fed steers. Differences in blood sugar in any of the steers were not associated with the intake of molasses indicating that sugar consumption did not affect the blood sugar in the systemic circulation. Observations were made at frequent intervals after feeding to determine if any clinical ill effects resulted from urea feeding. All steers appeared normal during the first 21 days of the experiment. Steers 1 and 2 showed no adverse effects from consuming an average of 454 and 530 grams of urea respectively daily during the last period of 18 days. This amounted to over 100 grams of urea per 100 lbs. body weight per day. During the last 18 days, steers 3, 4, and 5 were treated as shown in Table 16. Steer 3 was given, by stomach tub, two pounds of a 5:1 molasses-urea mixture after a 12 hour fast. Steer 4 was given, by stomach tube, two pounds of a 5:1 corn-urea mixture after a 12 hour fast. It was not possible to get all of the corn into steer 4 as part of it was too coarse for the stomach tube. Both steers showed typical symptoms of the effects of ingesting large quantities of urea. The first symptoms noted were a staggering gait and poor coordination. The steers stood with their front feet braced forward, their heads down, then showed a few tremors. Respiration and pulse rate increased followed by severe tetanic convulsions as the steers went down. Then the steers bloated and convulsions became worse. Merely touching the steers or taking blood samples would result in such severe convulsions that sometimes the heart would stop beating for a few seconds. This was followed by weakness, coma and regurgitation of rumen contents. Respiration was weak and it produced a gurgling sound. A sharp increase in blood ammonia and blood sugar resulted. Blood urea increased but not as high as for the steers on a full feed of the molasses-urea mixtures. Finally, death occurred about 2 hours after urea administration. It has been suggested that fermenting sugars in the rumen would produce organic acids which should protect the steers from the toxic effects of the liberated ammonia. There is no indication that molasses was of any benefit in reducing the toxicity resulting from the administration of urea. Hoflund _et al_., (1949) found that sugar added to the rumen of a sheep decreased the pH of the ingesta.

Steer 3 was given 2 liters of 5 percent glutamic acid in physiological salt solution, intravenously, as suggested by Sapirstein (1943) to relieve ammonia poisoning. This was started about 45 minutes after drenching but the glutamic acid appeared to be of no benefit. Ten gm. of chloral hydrate in 600 c.c. of water was then injected intravenously. This stopped the convulsions, but the steer remained in a coma. Then 300 c.c. of 23 percent calcium gluconate was administered intravenously but the steer died in spite of the therapy.

The only treatment given steer 4 was 600 c.c. of dextrose injected intravenously. This steer exhibited the same symptoms and had the same general blood picture as steer 3.

At the time of this experiment, we had no experimental record of an animal consuming sufficient amounts of urea to give toxic effects. The steers which were "on feed" and fed 4 lbs. of molasses-urea mixtures did not show toxic symptoms. There was no experimental information available as to the effect of feeding urea to fasted cattle. Steer 5 had been on molasses, hay and cottonseed meal for 21 days and appeared to relish large quantities of molasses. This steer was given water free choice and fasted 48 hours. At the end of this time, five lbs. of a 5:1 molasses-urea mixture was placed before him. The steer readily consumed two lbs. of the mixture in fifteen minutes then quit eating. This steer exhibited the same toxic symptoms and had blood values similar to that of the other steers. This steer was treated with intravenous injection of 100 grams of glutamic acid buffered with Na_2CO_3 in 1800 c.c. of saline solution but the treatment did not appear to be beneficial. Death followed in about the same time as with the other two steers. Samples of the supernatant liquid taken from the rumen and abomasum of steer 5 within 60 minutes after death had the following composition:

	Urea Mg. Percent	Ammonia Mg. Percent	Sugar Mg. Percent
Rumen	32.5	180.2	25
Abomasum	24.4	49.4	18

These analyses were started within 90 minutes after the death of the steer. They show that most of the urea had been converted to ammonia and that the highest concentration of urea and ammonia was in the rumen and not in the abomasum. The observed urea blood levels for the steers showing toxicity was not above 25 mg. percent while one steer daily consuming 7 lbs. of 6:1 molasses-urea mixture had a urea blood level of 95 mg. percent. The highest observed blood ammonia level for the non-fasting steers consuming molasses-urea mixtures was 1.7 mg. percent while the blood ammonia values went as high as 8 mg. percent for the fatalities. This is in agreement with the work of Dinning et al., (1948) who demonstrated that the toxicity was due to ammonia in the blood and not to the urea in the blood. Blood sugar levels were observed as high as 360 mg. percent for the steers showing advanced symptoms of toxicity resulting from ingestion of urea. The hyperglycemia was probably due to the release of adrenalin and not due to the ingested sugars. Steer 2 drenched with the corn-urea mixture exhibited hyperglycemia even before the dextrose was injected.

Personal communications have indicated that urea had been mistaken for salt and fed with salt or other minerals. In a later study a 245 lb. steer which had been without salt for several days was offered a urea salt mixture, but the steer refused to eat the mixture. After a 24 hour fast, this steer consumed 83 grams of urea in a 5:1 molasses-urea mixture. Toxic symptoms appeared within 20 minutes after the steer was fed. This steer frequently kicked at his stomach before the symptoms became severe. Other observed symptoms were the same as previously descirbed. The first treatment used was 250 c.c of Thiadex solution (containing trypan blue) injected intravenously because it has been used in treating urea toxicity found in field cases. No apparent benefit was obtained from this so 450 c.c. of dilute acetic acid (1 N) was injected into the rumen as suggested by Clark et al., (1951). They had demonstrated that dilute acetic acid given intravenously or directly into the rumen of sheep completely alleviated the toxic symptoms resulting from oral administration of urea to lambs. The steer appeared to get no benefit from the treatments so 10 grains of nembutal were given intravenously to the steer. The steer relaxed but died 138 minutes after he was fed the molasses urea mixture.

After a 24 hour fast, a 345 lb. steer consumed 54 gm. of urea in a molasses-urea mixture within 15 minutes and refused to eat more. No toxic symptoms were noted. This was equivalent to 16 mg. of urea/ 100 lbs. body weight.

A 330 lb. heifer was given by stomach tube, 66 mg. of urea in a 5:1 molasses urea mixture after a 24 hour fast. This was equivalent to 20 gms. of urea per 100 lbs. of body weight. The heifer bloated slightly within 20 minutes but showed no toxic symptoms.

TABLE 15

Results of Feeding Molasses-urea Mixtures to Steers

Days on Feed	Steer 1 Molasses-Urea 8:1 Blood Analysis in mg./Percent			Steer 2 Molasses-Urea 7:1 Blood Analysis in mg./Percent			Steet 3 Molasses-Urea 6:1 Blood Analysis in mg./Percent			Steer 4 Molasses-Urea 5:1 Blood Analysis in mg./Percent			Steet 5 Corn,C.S.M. and Hay Blood Analysis in mg./Percent		
	Urea	NH_4	Sugar	Urea	NH_4	Sugar	Urea	NH_4	Sugar	Urea	NH_4	Sugar	Urea	NH_4	Sugar
0	7.8	0.2	65	13.8	0.4	65	11.5	0.4	63	9.6	0.2	68	6.9	0.5	66
				4 pounds of molasses-urea mixture + 6 pounds of hay per day											
1															
2	21.4	0.9	70	22.3	0.9	73	23.4	1.0	75	19.3	1.0	70	14.5	0.2	70
3															
4	46.0	1.0	68	54.4	0.9	66	46.0	0.9	66	47.3	0.7	68	11.1	0.2	68
5															
6	35.6	1.2	68	45.4	0.5	63	56.1	0.7	66	54.8	0.9	66	10.1	0.5	70
7															
				8 pounds of molasses-urea mixture + 5 pounds of hay per day											
1															
2	69.6	1.0	60	67.4	0.9	58	61.3	0.9	57	65.2	1.0	64	9.6	0.4	60
3															
4	66.8	1.1	70	71.4	0.9	74	57.1	0.9	72	57.1	1.4	77	7.8	0.3	75
5															
6	65.7	1.0	60	79.9	0.7	60	65.7	1.0	60	55.9	1.7	61	6.1	0.2	64
7															
	4 pounds Dupont A + hay			4 pounds Dupont B + hay			4 pounds Dupont B + hay			4 pounds Dupont A + hay					
7	Refusals were so high for products A and B that this was discontinued (7-24-50). Steers 1, 2, 3, and 4 lost weight but appeared healthy.														
	8 pounds molasses-urea mixture + 6 pounds of hay per day														
1	(Molasses-urea 6:1)			(Molasses-urea 5:1)											
3	53.1	1.0	65	59.7	1.4	68									
6	67.6	1.1	65	69.9	1.0	60									
9	94.9	1.0	66	74.8	1.1	63	See Table 16			See Table 16			See Table 16		
12	67.6	1.1	64	73.4	0.9	64									
15	79.3	1.0	63	69.6	1.0	66									
18															

TABLE 16

Results of Administering Urea into the Rumen of Steers and Feeding after a 48 Hour Fast

Minutes After Drench	Blood Analysis Urea Mg Percent	NH_3 Mg Percent	Sug. Mg Percent	Symptoms	Treatment
				Steer 3	
0	8.8	0.2	60		
	2 lbs. 5:1 molasses urea administered into rumen				
30				Staggering gait, then tetanic convulsions	
45	22.1	3.3	160	Tetanic convulsions, rapid pulse and respiration	Inj. I.V. 2,000 cc 5 percent glutanic acid in saline
75		4.5		Severe tetanic convulsions. Slight bloat	Relieved bloat by moving steer
105	25.0	6.5	350	Tetanic convulsions and fatigue	10 gms. chloral hydrate in 600 cc H_2O injected I.V.
110				Weakness, bloat but no convulsions, coma	300 cc 23 percent calcium gluconate injected I.V.
120	25.0	7.0	260	Death	
				Steer 4	
0	8.8	0.3	60	Normal	
	2 lbs. 5:1 corn-urea administered into rumen (was not possible to give all the coarsely ground corn)				
40				Slight staggering, Ataxia	
60	14.1	2.6	158	Tetanic convulsion	
90				Convulsions, bulging eyeballs, coma	600 cc dextrose injected I.V.
135	21.4	5.5	300	Death	

TABLE 16 (Continued)

Results of Administering Urea into the Rumen of Steers and Feeding after a 48 Hour Fast

Minutes After Drench	Blood Analysis Urea Mg Percent	NH_4 Mg Percent	Sug. Mg Percent	Symptoms	Treatment
			Steer 5		
0	9.6	0.4	60	Normal	
	Consumed 2 lbs. 5:1 molasses urea in 15 minutes				
30				Incoordination, Ataxia	
50	14.9	3.6	180	Tetanic convulsions	Injected I.V. 50 gm. glutanic acid in 800 cc.
60				Slightly relieved	
80	17.1	5.3	200	Fatigue, convulsions	Injected I.V. 50 gms. glutamic acid in 1 liter (buffered with 3 percent Na_2Co_3) saline
125		8.2		Death	

PART III

THE EFFECT OF PURIFIED CARBOHYDRATES ON DIGESTION IN LAMBS

Rumen microorganisms have some preference as to the type of substrates which they attack due to differences in the complexity of substances. Feeds for ruminants are made up of various types of carbohydrates. Roughages are made up primarily of complex carbohydrates such as cellulose while concentrates are usually low in cellulose and high in starch. Cane molasses consisting primarily of sucrose and wood molasses consisting of glucose have been used as substitutes for grains in rations for ruminants. Lactose is the principle carbohydrate in milk which is the natural food for young animals. Calves and lambs are sometimes kept on milk even after the rumen is developed. Differences in digestibility of carbohydrate feeds have been reported, therefore, it was desirable to determine the effect of glucose, sucrose, and lactose on digestion.

Experimental Procedure

Twelve crossbred wethers averaging 68 lbs. were used in this study. The lambs were individually fed during standard 10-day preliminary periods preceding 10-day collection periods. During the preliminary period, the lambs were kept on wood shavings with provisions for individual feeding. During the collection period, the lambs were kept in metabolism stalls as described by Briggs and Gallup (1949). Six of the lambs were on the preliminary period and six on collection at each time. The lambs were fed twice daily and water was kept before them at all times except during the two feeding periods of approximately one hour each.

The feces were weighed daily, aliquoted and the samples preserved by refrigeration. Urine was measured daily, aliquoted and the samples acidified with HCl and preserved by refrigeration. Chemical analyses were carried out on feeds, feces and urine as described by the Association of Official Agricultural Chemists (1940).

The hay used in this experiment was coarsely chopped average quality prairie hay obtained in the vicinity of Stillwater, Oklahoma. The carbohydrates used were of purified edible grades. The soybean meal was commercial solvent extracted soybean meal. For each ration the purified carbohydrates, soybean meal and minerals were mixed together in a "Hobart" mixer in quantities sufficient to last for several days. The minerals consisted of salt, bonemeal, sodium sulfate, and a trace mineral mixture. Cod liver oil was added to each feed to supply adequate amounts of vitamins A and D for the lambs.

Results and Discussion

The rations fed and the chemical composition of the ration ingredients are given in Table 17. The only differences in the rations are the differences in the purified carbohydrates. An attempt was made to get the feed consumption above 700 gm. per day, but several of the lambs had feed refusals when higher amounts were fed so all lambs were limited to 700 gm. daily.

The average apparent digestion coefficients and nitrogen balance values for each ration are given in Table 19. There were no statistically significant differences in the digestion coefficients and nitrogen balance values among the three rations. The lambs grew a small amount throughout the experiment as evidenced by a positive nitrogen balance by all lambs except one on ration B which was in negative nitrogen balance.

Colòvas et al., (1949) compared the effect of adding cane molasses and wood molasses to hay rations for ruminants and found that cane molasses did not decrease the digestibility of crude protein as much as wood molasses. This difference may have been due to a difference in mineral content or something other than the type of carbohydrate. Cane molasses consists primarily of sucrose while wood molasses consists of glucose. Burroughs et al., (1951 b) reported that the ash of cane molasses is beneficial in cellulose digestion and urea utilization in in vitro studies.

TABLE 17

Daily Amounts and Chemical Composition of Feeds used in the Lamb Metabolism Study

Feed	Daily Allowance in Rations			Dry Matter	Percentage Composition of Dry Matter				
	A	B	C		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
	gm.	gm.	gm.	Percent					
Prairie Hay	350	350	350	91.17	92.50	4.77	2.11	32.50	53.15
Sucrose	224			100.00	100.00				100.00
Glucose		224		100.00	100.00				100.00
Lactose			224	100.00	100.00				100.00
Soybean meal	112	112	112	91.37	93.00	48.50	4.48	5.76	34.27
Minerals	14	14	14	98.73	8.54	3.35			5.19

TABLE 18

Chemical Composition of the Rations Fed Lambs

Ration	Percentage Composition of Dry Matter				
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	93.37	9.90	1.72	16.62	65.14
B	93.37	9.90	1.72	16.62	65.14
C	93.37	9.90	1.72	16.62	65.14

TABLE 19

Average Apparent Digestion Coefficients and Nitrogen Balance Values for Lamb Metabolism Study

Rations	Trials	Apparent Percentage of Digestibility						Nitrogen
		Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Balance
								gm.
A	11	68.2	70.5	58.8	41.5	52.1	77.8	1.66
B	12	69.6	72.0	60.2	46.9	55.1	78.7	1.19
C	12	67.4	69.7	57.4	41.6	50.8	77.2	1.31

PART IV

THE EFFECT OF AUREOMYCIN ON DIGESTION IN STEERS

Experiments with several species of animals have demonstrated that aureomycin and other antibiotics have a pronounced effect on micro-organisms in the gastrointestinal tract. The ruminant is primarily dependent upon an active microbial flora for efficient digestive processes. An experiment was undertaken, therefore, to determine the effect of aureomycin on the digestion of feed by steers.

Experimental Procedure

Six Hereford steers weighing about 620 pounds were used in this digestion experiment. The steers were kept in metabolism stalls with provisions made for separate collection of feces and urine. They were fed a constant amount of ration during 10-day preliminary and 15-day collection periods. Digestibility of nutrients and nitrogen retention were calculated from the chemical analyses of feeds and excreta. Blood samples were taken periodically for the determination of blood urea. All other experimental techniques were similar to those reported by Briggs and Gallup (1949).

The composition of the daily ration fed each steer during collection periods is given in Table 20. The digestibility of these rations without the addition of aureomycin had been determined with these same steers in a previous series of digestion trials shown in the second metabolism study with steers in Part I of this thesis. In the previous experiment, each of the steers were fed the basal ration and the urea ration during 10-day preliminary and 10-day collection periods. No feed refusals or digestive disturbances were observed during the entire period of approximately four months.

Prior to initiation of the present experiment it was necessary to obtain information on the approximate maximum amount of aureomycin which could be included in a ration without interfering with continued feed consumption. A level of 0.6 gm. per day was found to produce a marked anorexia and a severe fetid diarrhea within 48 to 72 hours. This condition persisted for 4 to 5 days after aureomycin feeding was discontinued. The anorexia appeared to be due to a digestive disturbance and not to unpalatability of the ration. The feeding of 0.2 gm. per day did not appear initially to interfere with a constant daily feed intake.

Aureomycin feeding was discontinued until the appetite and digestive processes appeared normal. A standard 10-day preliminary period was then conducted during which each steer was fed a constant amount of the assigned ration without aureomycin. Aureomycin (0.2 gm.) was then added to the rations of steers 1, 2, 3, and 6. Steers 4 and 5 were continued on the basal ration. Urine and feces collections were started immediately.

Results and Discussion

The digestion coefficients, nitrogen retention, and blood urea levels determined in the previous experiment during which the steers were fed the rations without aureomycin are given in Table 21, part A. The values for consecutive 3-day periods following the addition of aureomycin to the rations are given in part B of Table 21. The third day after aureomycin feeding was started steers 1 and 2 developed a mild anorexia and diarrhea. Steer 2 continued to refuse feed and had to be removed from the experiment. About the fifth day, steers 1, 3, and 6 became slightly constipated and developed a "paunchy" or bloated appearance and their feces became dry and fibrous. During the last three days of the experiment, steer 3 developed such a severe fetid diarrhea and marked anorexia that digestion coefficients were not calculated for this final 3-day period. Steers 4 and 5 consumed their rations and no digestive disturbance was noted.

Data in Table 21 show that the most pronounced effect of aureomycin was to decrease the digestibility of crude fiber, which suggests that it had a detrimental effect on the cellulytic microorganisms in the gastrointestinal tract. In periods 4 and 5 the digestibility of dry matter was decreased to less than 60 percent and crude fiber digestibility was decreased to less than 45 percent. Aureomycin also decreased the digestibility of nitrogen-free extract. Steers fed aureomycin had higher blood urea levels than when aureomycin was not fed. The results of this experiment have recently been reported by Bell _et_ _al_., (1951).

Colby _et_ _al_., (1950) fed 0.1 gm. of aureomycin daily to fattening lambs and found a decrease in feed consumption accompanied by a loss of weight. Rusoff (1951) obtained an increase in average daily gain from feeding 90 to 181 mg. of aureomycin daily to young dairy calves. He started with 14 week old calves and obtained a higher average daily gain through the next 14 weeks for the aureomycin fed calves than for the controls.

TABLE 20

Composition of Daily Ration (grams) for the Aureomycin Study

Ingredients	Steer Number and Ration Identification					
	1	2	3	4	5	6
	Urea + Aureo-mycin	Basal + Aureo-mycin	Basal + Aureo-mycin	Basal	Basal	Urea + Aureo-mycin
Prairie Hay	1800	1800	1800	1800	1800	1800
Corn	1730	1730	1730	1730	1730	1730
Soybean Oil Meal	70	70	70	70	70	70
Urea	45					45
Bone Meal	50	50	50	50	50	50
Salt	30	30	30	30	30	30
Aureomycin	0.2	0.2	0.2			0.2

TABLE 21

The Effect of Aureomycin on Digestion Coefficients, Nitrogen Retention, and Blood Urea

Steer Number	3-day Period		Percent Apparent Digestibility of Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Nitrogen Retention gm	Blood Urea mg %
(A) Average values obtained in previous experiment									
			Basal ration						
All			64.94	48.32	65.43	65.49	69.65	7.62	8.41
			Urea ration						
All			65.45	62.40	66.62	65.55	69.70	12.14	20.06
(B) Average values obtained in aureomycin experiment									
			Basal ration						
4 and 5	1		69.07	51.93	63.31	66.35	74.91	9.10	7.66
	2		68.38	52.68	58.58	62.77	74.93	7.67	6.59
	3		70.69	55.42	65.94	67.01	76.20	9.74	8.86
	4		69.37	55.15	66.93	65.45	75.40	10.27	7.10
	5		72.67	60.83	71.52	70.60	77.96	13.03	5.34
		Av.	70.04	53.20	65.26	66.44	75.88	9.96	7.11
			Basal ration plus aureomycin						
3	1		76.38	65.64	74.63	66.29	81.86	17.74	15.43
	2		63.71	56.27	62.76	49.71	70.48	9.63	14.24
	3		58.00	47.60	66.31	35.88	67.25	9.60	13.41
	4		54.06	45.31	60.50	30.72	63.49	1.66	20.38
			Urea ration plus aureomycin						
1 and 6	1		74.58	72.10	71.58	69.98	79.65	14.38	21.11
	2		66.23	67.46	62.77	52.70	73.52	6.79	22.06
	3		63.84	65.05	65.44	51.37	70.20	6.46	22.63
	4		59.53	68.42	67.57	39.78	66.79	6.96	23.78
	5		59.58	67.86	65.13	42.86	66.89	9.04	22.24

SUMMARY

Studies were conducted with ruminants to determine the metabolism of urea nitrogen with various carbohydrate feeds, the effect of feeding high levels of urea, the utilization of purified carbohydrates and the effect of aureomycin on digestion.

The addition of urea to rations containing corn, sweet potatoes, barley, milo and cane molasses significantly increased the nitrogen retention by steers. Urea significantly increased the apparent digestibility of crude protein but had no effect on the digestibility of other ration nutrients. Significant differences were obtained in the apparent digestibility of ration nutrients and in the biological value of the protein among some of the carbohydrate feeds.

Four steers were induced to consume as much as 454 gm. of urea in cane molasses daily for several days without any ill effects. Two steers given 150 gm. of urea by stomach tube exhibited toxic symptoms followed by death within 135 minutes. After a 48 hour and a 24 hour fast, two steers voluntarily consumed 150 gm. and 83 gm of urea in molasses which proved fatal. The antidotes used did not relieve this toxic condition. Toxic symptoms were accompanied by a rapid increase in blood ammonia, blood urea and blood sugar. However, much higher blood urea values were obtained from steers which were consuming as much as 454 gm. of urea over a period of 24 hours. After a 24 hour fast, two calves voluntarily consumed 54 and 66 gm. of urea in molasses within 15 minutes and the steers showed no ill effects.

No differences in nitrogen balance values or in the digestibility of

ration nutrients were obtained from feeding rations containing sucrose, glucose, or lactose to lambs.

The feeding of 0.2 gm. of aureomycin daily to steers resulted in a marked reduction in the digestibility of crude fiber accompanied by some digestive distrubances. When 0.6 gm. of auroemycin was fed daily, it produced a marked anorexia and a fetid diarrhea within 48 to 72 hours.

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APPENDIX

Complete Data for Metabolism Studies

TABLE 22

Average Daily Nitrogen Balance and Biological Value Data
of the Corn and Sweet Potato Metabolism Study

Ration Identification	Trial No.	Steer No.	Intake		Excretion		N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
			Dry Matter	N	Fecal N	Urinary N						
	1	1	4544	52.9	26.9	19.4	6.6	24.1	8.0	50.2	38.7	77.1
A	5	4	4497	51.3	26.2	22.7	2.4	23.8	8.1	48.9	34.3	70.1
	7	1	4568	50.8	24.3	18.9	7.6	24.2	8.0	50.7	39.9	78.5
Corn	8	3	4467	51.7	27.6	14.4	9.7	23.7	8.1	47.8	41.5	86.9
	9	4	4479	51.9	24.4	22.3	5.2	23.7	8.2	51.2	37.2	72.7
	Av.		4511	51.7	25.9	19.5	6.3	23.9	8.1	49.8	38.3	77.1
B	2	1	4560	73.3	25.2	30.3	17.7	24.2	8.0	72.2	49.8	69.0
	4	4	4549	71.6	25.6	30.6	15.4	24.1	8.0	70.1	47.5	67.8
Corn +	5	3	4565	72.6	27.0	23.7	21.9	24.2	8.0	69.8	54.1	77.4
	7	4	4597	71.8	24.2	34.0	13.6	24.4	8.1	72.0	44.5	61.9
Urea	8	1	4512	73.1	26.6	28.9	17.6	23.9	8.1	70.5	49.7	70.5
	9	3	4529	72.9	25.7	29.1	18.1	24.0	8.3	71.2	50.4	70.7
	Av.		4552	72.5	25.7	29.4	17.4	24.1	8.1	71.0	49.3	69.5
C	2	4	4423	51.8	30.5	13.8	7.5	23.4	8.0	44.7	38.9	87.0
	4	1	4500	50.5	33.6	14.4	2.5	23.9	8.0	40.3	33.9	84.2
Sweet	6	2	4439	50.5	30.3	13.4	6.8	23.5	7.9	43.7	38.3	87.5
	7	3	4517	48.5	28.8	13.1	6.6	23.9	8.1	43.6	38.6	88.5
Potatoes	8	4	4463	52.0	34.6	14.3	3.1	23.7	8.2	41.0	34.9	85.2
	9	1	4480	51.8	30.8	16.0	5.0	23.7	8.3	44.8	37.1	85.8
	11	1	4318	51.9	31.8	14.3	5.8	22.9	8.3	43.0	37.0	86.0
		3	4318	51.9	29.9	16.0	6.0	22.9	8.3	45.0	37.3	82.9
		4	4318	51.9	29.1	15.4	7.4	22.9	8.4	45.7	38.7	84.7
	Av.		4420	51.2	31.1	14.5	5.6	23.4	8.2	43.5	37.2	85.3

TABLE 22 (Continued)

Average Daily Nitrogen Balance and Biological Value Data
of the Corn and Sweet Potato Metabolism Study

Ration Identification	Trial No.	Steer No.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
D	1	4	4549	73.2	34.8	26.5	11.9	24.1	7.9	62.6	44.0	70.2
	4	3	4550	71.5	35.4	19.3	16.8	24.1	7.9	60.2	48.9	81.2
Sweet	5	1	4566	72.5	36.6	24.0	11.9	24.2	8.0	60.1	44.1	73.5
Potatoes	10	1	4329	73.3	35.7	21.0	16.6	22.9	8.4	60.5	47.9	79.2
		2	4329	73.3	32.5	21.1	19.8	22.9	8.1	63.9	50.9	79.7
+ Urea		3	4329	73.3	30.8	22.5	20.0	22.9	8.3	65.3	51.3	78.4
		4	4329	73.3	37.3	20.0	16.0	22.9	8.4	59.0	47.3	80.3
		2	4368	71.9	33.2	23.7	15.0	23.2	8.1	61.8	46.2	74.8
	Av.		4419	72.8	34.5	22.3	16.0	23.4	8.1	61.7	57.6	77.2

TABLE 23

Apparent Digestion Coefficients of the Corn and Sweet Potato Metabolism Study

Ration Identification	Trial No.	Steer No.	Dry Matter Intake	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	1	1	4544	65.7	67.9	49.0	72.2	64.4	70.1
	5	4	4497	69.2	71.2	48.8	73.8	65.1	74.3
Corn	7	1	4568	70.9	72.5	52.3	66.9	65.9	76.5
	8	3	4467	59.9	61.4	46.7	59.4	53.7	66.5
	9	4	4479	70.7	72.8	52.9	68.9	63.9	76.4
	Av.		4511	67.3	69.2	49.9	68.2	62.6	72.8
B	2	1	4560	70.4	72.5	65.4	75.3	68.5	74.9
	4	4	4549	72.6	74.9	64.1	81.6	71.0	77.6
Corn	5	3	4565	72.9	74.9	62.8	75.5	61.6	80.2
	7	4	4597	74.7	76.9	66.3	80.0	71.2	80.2
+ Urea	8	1	4512	68.7	7017	63.8	68.5	64.9	73.9
	9	3	4529	69.6	72.9	64.7	76.4	63.5	77.0
	Av.		4552	71.5	73.8	64.5	76.2	66.8	77.3
C	2	4	4423	68.1	71.0	41.6	71.9	56.3	78.1
	4	1	4500	67.7	69.8	33.5	54.5	49.2	79.0
Sweet	6	2	4439	64.1	65.5	40.2	57.9	42.8	74.2
	7	3	4517	63.8	65.5	43.0	49.9	62.3	71.2
Potatoes	8	4	4463	65.6	68.2	33.6	49.4	50.9	76.9
	9	1	4480	67.8	69.7	40.6	48.6	48.5	79.0
	11	1	4318	65.7	67.7	38.7	52.8	46.0	76.7
		3	4318	64.5	66.3	42.4	51.4	43.5	74.9
		4	4318	66.9	69.0	43.9	48.1	52.1	76.5
	Av.		4420	66.0	68.1	39.7	53.8	50.2	76.3
D	1	4	4549	66.4	69.1	52.4	40.8	47.0	77.9
	4	3	4550	67.1	69.4	50.5	51.0	50.9	77.9
Sweet	5	1	4566	65.2	67.2	49.5	49.4	43.4	76.7
Potatoes	10	1	4329	67.5	69.9	51.1	51.3	55.1	78.0
		2	4329	68.5	70.4	55.9	51.1	53.6	78.4
+ Urea		3	4329	66.9	69.1	57.9	54.1	48.5	77.4
		4	4329	67.7	70.3	49.1	46.8	57.0	78.6
	11	2	4369	68.3	70.4	54.3	45.4	53.9	78.4
	Av.		4419	67.2	69.5	52.6	48.7	51.2	77.9

TABLE 24

Average Daily Nitrogen Balance and Biological Value Data of the corn, Barley, and Milo Metabolism Study

Ration Identification	Trial No.	Steer No.	Intake		Excretion		N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
			Dry Matter	N	Fecal N	Urinary N						
A	1	1	3379	43.5	23.4	13.6	6.5	17.9	7.3	38.1	31.7	83.4
	2	2	3398	43.3	25.3	14.8	3.2	18.0	7.3	36.0	28.5	79.1
Corn	3	3	3394	43.9	25.1	13.2	5.6	18.0	7.0	36.8	30.5	82.9
	4	4	3340	45.4	25.6	13.9	5.9	17.7	7.2	37.6	30.9	82.1
	5	5	3358	45.1	20.1	15.3	9.7	17.8	7.4	42.8	34.9	82.7
	6	6	3328	44.9	20.9	13.6	10.4	17.7	7.4	41.7	35.4	85.0
	Av.		3366	44.4	23.4	14.1	6.9	17.9	7.3	38.8	32.0	82.5
B	1	2	3424	62.4	26.4	27.1	8.9	18.2	7.3	54.1	34.4	63.5
	2	3	3443	62.2	22.3	27.8	12.1	18.3	7.0	58.1	37.4	64.3
Corn +	3	4	3439	62.8	24.9	28.2	9.7	18.2	7.0	54.2	33.0	60.9
	4	5	3385	64.2	23.5	27.5	13.2	17.9	7.3	58.7	38.4	65.5
Urea	5	6	3395	63.8	24.2	26.2	13.4	18.0	7.4	57.6	38.8	67.4
	6	1	3400	64.4	24.5	27.7	12.2	18.0	7.3	57.9	37.6	64.9
	Av.		3414	63.3	24.3	27.4	11.6	18.1	7.2	56.8	36.6	64.4
C	1	3	3286	41.9	20.4	11.8	9.7	17.4	7.0	38.5	33.8	87.7
	2	4	3402	42.9	21.2	15.4	6.3	18.0	7.1	39.8	31.4	78.9
Barley	3	5	3398	43.6	21.3	17.9	4.4	18.0	7.2	40.3	29.6	73.5
	4	6	3344	45.0	21.7	15.7	7.6	17.7	7.4	41.1	32.7	79.7
	5	1	3354	44.6	21.4	17.7	5.5	17.8	7.3	41.0	30.5	74.5
	6	2	3357	45.1	21.8	15.5	7.8	17.8	7.4	41.1	33.0	80.3
	Av.		3357	43.9	21.3	15.7	6.9	17.8	7.2	40.3	31.8	79.1
D	1	4	3352	61.4	20.8	28.8	11.8	17.8	7.1	58.4	36.7	62.8
	2	5	3446	61.8	20.1	29.9	11.8	18.3	7.2	59.9	37.2	62.2
Barley	3	6	3442	62.5	22.8	29.8	9.9	18.2	7.2	57.9	35.4	61.1
	4	1	3388	63.9	23.0	28.5	12.4	18.0	7.3	58.9	37.6	63.9
+ Urea	5	2	3398	63.5	22.6	32.5	8.4	18.0	7.4	58.9	33.7	57.2
	6	3	3402	64.0	19.5	32.3	12.2	18.0	7.2	62.5	37.4	59.8
	Av.		3405	62.9	21.5	30.3	11.1	18.1	7.2	59.4	36.3	61.2

TABLE 24 (Continued)

Ration Identification	Trial No.	Steer No.	Intake: Dry Matter	Intake: N	Excretion: Fecal N	Excretion: Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
E	1	5	3379	43.1	26.5	13.1	3.5	17.9	7.4	34.5	28.8	83.3
	2	6	3393	42.9	26.1	12.8	4.0	18.0	7.3	34.8	29.3	84.3
Milo	3	1	3375	44.2	25.8	14.8	3.6	17.9	7.3	36.2	28.7	79.0
	4	2	3335	45.0	30.0	12.5	2.5	17.7	7.3	32.6	27.5	84.3
	5	3	3345	44.5	26.2	12.9	5.4	17.7	7.1	36.0	30.3	83.9
	6	4	3350	45.1	24.2	12.4	8.5	17.8	7.3	38.6	33.5	86.8
	Av.		3362	44.1	26.5	13.1	4.6	17.8	7.3	35.5	29.7	83.6
F	1	6	3353	61.5	29.5	22.5	9.5	17.8	7.3	49.7	34.6	69.5
	2	1	3438	61.7	25.6	27.4	8.7	18.2	7.2	54.3	34.2	62.9
Milo +	4	3	3380	63.8	28.5	25.8	9.5	17.9	7.1	53.2	34.5	64.8
	5	4	3390	63.4	27.4	23.7	12.3	18.0	7.2	54.0	37.5	69.4
Urea	6	5	3395	63.9	21.8	28.1	14.0	18.0	7.5	60.1	39.4	65.6
	7	2	3406	63.7	26.5	28.0	9.2	18.1	7.5	55.3	34.7	62.7
	Av.		3394	63.0	26.6	25.9	10.5	18.0	7.3	54.4	35.8	65.8
G	7	3	3413	64.2	20.8	28.0	15.4	18.1	7.2	61.5	40.6	66.1
	7	4	3413	64.2	22.0	26.6	15.6	18.1	7.3	60.3	41.0	68.0
Special	7	6	3413	64.2	23.2	27.6	13.4	18.1	7.2	59.1	38.8	65.6
	8	1	3353	63.3	20.9	32.9	9.5	17.8	7.3	60.1	34.5	57.4
	8	2	3353	63.3	21.9	31.8	9.6	17.8	7.5	59.1	34.8	58.9
	8	5	3353	63.3	17.9	31.6	13.6	17.8	7.5	63.1	38.9	61.6
	Av.		3383	63.7	21.1	29.8	12.8	17.9	7.3	60.5	38.1	62.9

TABLE 25

Apparent Digestion Coefficients of the Corn, Barley and Milo Metabolism Study

Ration Identification	Trial No.	Steer No.	Dry Matter Intake	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	1	1	3379	63.2	64.9	46.4	63.8	69.3	65.9
	2	2	3398	61.0	62.6	41.6	62.1	67.0	63.9
Corn	3	3	3394	62.8	64.7	42.9	63.2	63.1	68.0
	4	4	3340	61.0	63.0	43.5	64.9	63.4	65.4
	5	5	3358	69.9	71.6	55.4	69.3	66.1	75.4
	6	6	3328	67.7	70.0	53.4	65.9	65.7	73.6
	Av.		3366	64.3	66.1	47.2	64.9	65.8	68.7
B	1	2	3424	60.3	61.2	57.7	66.4	69.4	61.1
	2	3	3443	67.2	68.4	64.1	66.1	67.8	71.1
Corn	3	4	3439	62.7	63.8	60.4	64.9	66.9	65.4
	4	5	3385	63.7	65.3	63.6	68.8	61.3	68.4
+ Urea	5	6	3395	65.3	66.7	62.0	65.3	65.4	69.8
	6	1	3400	68.3	69.7	61.9	68.1	66.4	73.8
	Av.		3414	64.6	65.9	61.6	66.6	66.2	68.3
C	1	3	3286	63.2	65.0	51.5	55.4	59.0	68.7
	2	4	3402	62.3	64.4	50.7	34.1	60.2	68.3
Barley	3	5	3398	62.7	65.1	51.2	48.8	61.1	68.6
	4	6	3344	59.5	61.5	51.9	43.3	57.2	64.8
	5	1	3354	63.1	65.2	52.2	48.5	60.7	68.8
	6	2	3357	65.7	67.9	51.7	59.4	61.5	72.2
	Av.		3357	62.8	64.9	51.6	48.3	60.0	68.6
D	1	4	3352	61.6	63.3	66.2	47.2	57.3	67.2
	2	5	3446	63.7	65.2	67.3	44.4	58.8	69.3
Barley	3	6	3442	59.9	61.5	62.8	45.6	60.1	64.3
	4	1	3388	59.0	60.7	64.2	51.7	56.8	63.9
+ Urea	5	2	3398	65.1	67.0	64.5	51.6	65.6	70.3
	6	3	3402	67.8	70.0	69.6	58.5	60.7	74.9
	Av.		3405	62.9	64.6	65.8	49.9	59.9	68.3
E	1	5	3374	62.1	64.0	38.7	62.4	65.3	67.3
	2	6	3393	62.3	64.0	38.9	56.8	65.8	66.8
Milo	3	1	3375	63.9	65.7	41.5	64.4	64.5	69.3
	4	2	3335	57.4	59.5	33.1	67.4	63.7	61.3
	5	3	3345	63.2	65.1	41.1	70.5	60.4	69.8
	6	4	3350	65.6	68.3	46.1	68.6	67.6	71.3
	Av.		3362	62.4	64.4	39.9	65.0	64.6	67.6

TABLE 25 (Continued)

Ration Identification	Trial No.	Steer No.	Dry Matter Intake	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
F	1	6	3353	59.4	60.6	52.0	59.1	63.4	64.1
	2	1	3438	64.5	65.7	58.5	60.3	66.8	68.7
Milo	4	3	3380	60.8	62.1	55.4	54.8	58.3	66.9
	5	4	3390	65.2	66.6	56.8	64.1	65.6	70.6
+ Urea	6	5	3395	70.9	73.0	65.8	66.4	66.1	77.8
	7	2	3406	66.9	68.3	58.4	65.6	65.5	72.8
	Av.		3394	64.6	66.1	57.8	61.7	64.3	70.2
G	7	3	3413	71.2	72.5	67.6	64.6	65.3	76.3
	7	4	3413	66.7	68.4	65.9	63.6	63.9	70.7
Special	7	6	3413	67.3	69.2	63.9	59.0	61.5	73.3
	8	1	3353	67.0	69.7	67.0	58.7	64.3	72.0
	8	2	3353	65.6	68.3	65.3	58.5	63.2	70.5
	8	5	3353	68.0	70.4	71.7	62.7	63.4	72.4
	Av.		3383	67.6	69.8	66.9	61.2	63.6	72.5

TABLE 26

Average Daily Nitrogen Balance and Biological Value Data of the Corn and Molasses Metabolism Study

Ration Identification	Trial No.	Steer No.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
A	1	1	3379	46.1	20.8	13.7	11.6	17.9	7.1	43.2	36.6	84.7
	2	2	3352	45.5	20.4	12.9	12.3	17.8	7.5	42.9	37.6	87.5
Corn	3	3	3310	44.7	18.1	13.0	13.6	17.5	7.4	44.2	38.5	87.2
	4	4	3331	44.5	21.1	12.7	10.8	17.7	7.6	41.1	36.0	87.6
	6	6	3318	45.1	20.2	12.1	12.8	17.6	7.5	42.5	37.9	89.3
	Av.		3338	45.2	20.1	12.9	12.2	17.7	7.4	42.8	37.3	87.3
B	1	2	3424	65.0	20.6	24.8	19.5	18.2	7.4	62.5	45.1	72.1
	2	1	3397	64.4	19.5	25.0	20.0	18.0	7.1	62.9	45.1	71.7
Corn	3	3	3355	63.6	21.9	27.5	14.2	17.8	7.6	59.4	39.5	66.5
	4	4	3376	63.6	19.4	25.5	18.5	17.9	7.4	61.9	43.8	70.8
+ Urea	5	6	3413	64.5	22.7	22.8	19.1	18.1	7.3	60.0	44.5	74.2
	7	4	3363	64.0	20.7	27.2	16.1	17.8	7.6	61.1	41.4	67.8
	Av.		3388	64.2	20.8	25.5	17.9	18.0	7.4	61.3	43.2	70.5
C	1	3	3323	46.6	23.8	14.1	8.7	17.6	7.5	40.5	33.8	83.6
	2	4	3296	46.1	25.4	12.8	7.9	17.5	7.3	38.2	33.6	88.1
Corn +	3	6	3254	45.2	20.9	11.3	13.0	17.3	7.2	41.6	37.5	90.1
	5	1	3312	46.2	23.5	12.6	10.1	17.6	7.5	40.2	35.1	87.3
Molasses	6	2	3262	45.6	21.0	14.5	10.1	17.3	7.9	42.0	35.4	84.3
	7	3	3262	45.6	20.9	13.5	11.3	17.3	7.7	42.1	36.3	86.3
	Av.		3285	45.9	22.6	13.1	10.2	17.4	7.5	40.8	35.3	86.6
D	1	4	3368	65.5	20.9	29.9	14.7	17.9	7.3	62.4	39.8	63.8
Corn +	2	3	3341	64.9	22.3	31.2	11.3	17.7	7.5	60.5	36.7	60.8
	4	6	3320	63.9	22.2	25.5	16.2	17.6	7.3	59.3	40.2	67.8
Molasses	5	2	3357	65.0	24.9	27.9	12.2	17.8	7.8	57.9	37.8	65.3
	6	1	3307	64.5	22.3	28.6	13.6	17.5	7.5	59.7	38.6	64.7
+ Urea	7	1	3307	64.5	20.8	25.5	18.1	17.5	7.6	61.2	43.2	70.7
	Av.		3333	64.7	22.2	28.1	14.4	17.7	7.5	60.2	39.4	65.5

TABLE 26 (Continued)

Ration Identification	Trial No.	Steer No.	Intake		Excretion		N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	% Biological Value
			Dry Matter	N	Fecal N	Urinary N						
E	1	5	3265	47.1	21.7	13.3	12.1	17.3	7.2	42.7	36.6	85.7
	2	6	3238	46.5	25.6	12.0	8.9	17.2	7.2	38.0	33.2	87.4
Molasses	4	1	3217	45.5	24.2	13.0	8.3	17.1	7.3	38.3	32.7	85.3
	5	3	3254	46.6	24.4	16.6	5.7	17.3	7.7	39.5	30.6	77.6
	6	4	3204	46.0	25.0	15.8	5.2	17.0	7.5	38.0	29.7	78.2
	7	2	3204	46.0	23.0	12.4	10.7	17.0	7.9	40.0	35.6	88.8
	Av.		3230	46.3	24.0	13.8	8.5	17.2	7.5	39.4	33.1	83.8
F	2	5	3283	65.4	25.9	26.3	13.1	17.4	7.3	56.8	37.8	66.5
	3	1	3241	64.5	23.2	26.3	15.0	17.2	7.3	58.5	39.5	67.5
Molasses	4	2	3262	64.4	23.3	23.5	17.6	17.3	7.7	58.4	42.6	72.9
	5	4	3299	65.5	22.8	30.1	12.6	17.5	7.5	60.2	37.6	62.4
+ urea	6	3	3249	64.9	24.4	30.8	9.7	17.2	7.7	57.7	34.6	59.9
	7	6	3249	64.9	25.1	28.3	11.6	17.2	7.6	57.1	36.4	63.7
	Av.		3264	64.9	24.1	27.5	13.3	17.3	7.5	58.1	38.1	65.5

TABLE 27

Apparent Digestion Coefficients of the Corn and Molasses Metabolism Study

Ration Identification	Trial No.	Steer No.	Dry Matter Intake	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
A	1	1	3379	67.9	69.6	54.8	75.8	72.6	70.4
	2	2	3352	70.3	72.1	55.2	63.6	65.8	76.9
Corn	3	4	3310	70.5	72.3	59.7	74.6	71.4	74.2
	4	3	3331	67.4	69.9	52.7	68.3	69.9	72.2
	6	6	3318	70.4	71.9	55.2	71.0	67.9	75.3
	Av.		3338	69.3	71.2	55.5	70.7	69.5	73.8
B	1	2	3424	68.6	70.8	65.9	72.3	70.0	71.9
	2	1	3397	68.7	70.9	69.7	76.7	71.2	70.8
Corn	3	3	3355	67.8	69.8	65.6	69.9	68.6	71.0
	4	4	3376	69.0	70.2	69.5	72.8	70.5	70.1
+ Urea	5	6	3413	64.7	65.7	64.8	65.8	69.5	64.6
	7	4	3363	70.0	71.9	67.7	69.2	67.5	74.1
	Av.		3388	68.1	69.9	67.2	71.1	69.6	70.4
C	1	3	3323	67.9	70.4	49.0	68.9	67.3	74.5
	2	4	3296	68.7	70.8	45.0	63.6	69.1	75.4
Corn +	3	6	3254	69.0	70.8	53.9	67.9	67.9	74.2
	5	1	3312	68.1	69.3	49.1	60.2	70.7	72.2
Molasses	6	2	3262	73.1	75.2	54.2	64.9	71.3	79.8
	7	3	3262	70.9	73.3	54.3	67.5	69.0	77.5
	Av.		3285	69.6	71.6	50.9	65.5	69.2	75.6
D	1	4	3368	71.7	72.5	68.2	71.2	72.5	75.9
	2	3	3341	69.6	71.8	65.6	63.6	69.7	74.1
Corn +	4	6	3320	70.0	71.5	65.3	62.7	70.7	73.5
	5	2	3357	69.7	71.2	61.7	63.0	69.4	74.3
Molasses	6	1	3307	70.9	73.0	65.4	67.5	69.2	76.0
	7	1	3307	70.9	72.9	67.7	69.2	67.3	76.0
+ Urea	Av.		3333	70.5	72.2	65.6	66.2	69.8	75.0

TABLE 27 (Continued)

Ration Identification	Trial No.	Steer No.	Dry Matter Intake	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
E	1	5	3265	68.6	70.5	53.9	60.7	65.2	74.9
	2	6	3238	65.4	66.8	44.8	46.6	64.1	71.6
Molasses	4	1	3217	67.2	69.0	46.7	47.8	67.3	73.5
	5	3	3254	69.6	71.7	47.5	42.4	72.8	74.9
	6	4	3204	69.7	71.5	45.7	50.0	68.1	77.0
	7	2	3204	68.7	70.7	50.0	51.5	66.7	75.5
	Av.		3230	68.2	69.9	48.1	49.8	67.4	74.6
F	2	5	3283	67.2	69.3	60.4	49.6	68.6	72.0
	3	1	3241	67.8	69.8	64.0	49.3	65.2	73.2
Molasses	4	2	3262	68.8	70.7	63.8	49.5	67.5	73.9
	5	4	3299	69.2	70.7	65.3	46.8	71.6	72.3
+ Urea	6	3	3249	68.3	70.7	62.4	45.7	66.1	74.7
	7	6	3249	68.2	69.9	61.4	50.8	63.9	74.1
	Av.		3264	68.3	70.2	62.9	48.6	67.2	73.4

TABLE 28

Nitrogen Balance Values and Apparent Digestion Coefficients for Lambs in the Purified Carbohydrate Study

Ration Identification	Trial No.	Lamb No.	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Fecal N	Urinary N	N Balance
A	1	1	70.5	72.9	64.3	55.7	54.4	79.3	3.74	6.16	.56
		2	70.1	72.1	58.9	47.8	53.1	79.6	4.29	4.13	2.04
Sucrose	2	7	64.1	66.5	46.3	17.9	45.9	76.1	5.62	4.04	.80
		8	65.6	67.6	52.3	46.0	48.3	75.1	5.00	3.58	1.88
	3	3	72.5	75.0	58.9	49.9	65.1	80.7	4.29	4.28	1.89
		4	64.5	66.7	56.8	35.2	44.6	74.6	4.52	3.77	2.17
	4	9	64.1	66.7	53.0	12.7	45.4	75.7	4.90	4.41	1.15
		10	67.9	70.3	61.6	49.5	49.4	77.5	4.02	4.02	2.42
	5	5	71.4	73.9	66.4	48.3	54.0	80.7	3.51	5.60	1.35
		6	69.8	72.3	63.7	41.3	55.8	78.7	3.80	3.65	3.01
	6	11	69.5	72.0	64.3	52.4	57.3	77.4	3.72	5.77	.97
	Av.		68.2	70.5	58.8	41.5	52.1	77.8	4.31	4.49	1.66
B	1	3	69.9	72.7	58.1	46.1	57.6	79.5	4.37	5.79	.30
		4	69.4	71.7	56.6	41.6	55.2	79.0	4.54	4.94	.98
Glucose	2	9	66.2	68.5	49.2	50.0	49.0	77.0	5.30	6.12	- .96
		10	69.1	71.1	59.1	53.6	50.3	78.7	4.27	5.44	.74
	3	5	73.3	75.9	62.5	46.4	66.9	81.0	3.92	5.32	1.22
		6	74.0	76.3	64.8	50.2	64.6	81.7	3.68	4.68	2.10
	4	11	70.0	72.7	66.6	50.5	53.7	79.0	3.48	5.41	1.57
		12	66.4	68.7	54.7	27.3	47.6	77.2	4.73	5.04	.69
	5	1	68.2	70.8	58.7	49.6	54.7	77.3	4.32	6.01	.13
		2	68.2	70.6	62.7	49.0	51.1	77.4	3.90	3.99	2.57
	6	7	70.7	72.9	65.0	46.4	57.6	78.8	3.65	4.14	2.67
		8	69.2	71.5	63.9	52.6	53.0	77.9	3.78	4.46	2.22
	Av.		69.6	72.0	60.2	46.9	55.1	78.7	4.16	5.11	1.19

TABLE 28 (Continued)

Ration Identification	Trial No.	Lamb No.	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Fecal N	Urinary N	N Balance
C	1	5	65.5	67.7	54.3	39.7	47.3	75.7	4.78	5.49	.20
		6	65.6	68.2	51.5	30.1	48.2	76.9	5.08	4.99	.39
Lactose	2	11	66.5	68.4	62.0	48.1	43.0	76.4	3.97	5.29	1.40
		12	62.0	63.5	52.2	44.8	33.8	73.3	4.99	4.40	1.07
	3	1	68.3	71.2	56.1	39.0	59.2	77.4	4.60	5.78	.08
		2	71.4	73.6	62.8	44.1	59.1	79.8	3.88	3.77	2.81
	4	7	66.6	69.1	58.0	39.1	51.3	76.2	4.40	4.30	1.76
		8	69.3	71.5	57.0	45.9	56.3	78.3	4.50	4.02	1.94
	5	3	71.1	73.8	56.0	40.2	62.1	80.4	4.61	4.89	.96
		4	66.1	68.5	55.8	31.6	45.0	77.4	4.63	4.27	1.56
	6	9	69.3	71.3	62.1	47.2	54.2	77.6	3.97	4.26	2.23
		10	67.5	69.5	61.5	48.9	50.1	76.2	4.03	4.86	1.37
	Av.		67.4	69.7	57.4	41.6	50.8	77.2	4.45	4.69	1.31

TYPIST PAGE

THESIS TITLE: Digestion Studies with Steers and Lambs

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