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Nitrogen Metabolism In Dairy Cattle

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I. EFFICIENCY OF NITROGEN UTILIZATION BY LACTATING COWS FED VARIOUS FORAGES.

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INTRODUCTION

Milk production is a highly economical method for converting farm grown roughages and grain, especially the protein fraction, into human food. The efficient conversion of the major nutrients—crude protein, starch and fiber—of roughages and grain to casein, butterfat and lactose of milk depends mostly on their form and balance in the ration.

Because of the present trend toward the increased production of higher quality roughages, especially roughages of higher protein content, based on present feeding standards, many dairymen are now feeding higher levels of protein than cattle can efficiently use. Consequently the amount of protein supplement needed on the average dairy farm has decreased. With the present emphasis on efficiency of farm production it is appropriate to define more clearly the nutritional situation in which protein supplements are needed in dairy rations and ways of assuring the maximum utilization of protein and other nitrogenous compounds of the feed.

In the normal metabolism of cattle the ingested protein and non-protein nitrogenous compounds are subjected to the degradative and synthetic action of rumen bacteria and protozoa and are converted in part to microbial protein previous to the proteolytic enzyme digestion in the stomach and small intestine. The nitrogen absorbed from the digested nitrogenous compounds may be partitioned into that stored in the body tissues, secreted in the milk protein, excreted in the urine, and excreted in the feces along with the undigested and unabsorbed fractions. Unused nitrogenous compounds which have been absorbed into the blood and catabolized in the liver are excreted in the urine along with catabolized tissue nitrogen. Thus, under most conditions, the quantity of nitrogen excreted in the urine is the key to the efficiency with which absorbed nitrogen (protein) is utilized.

In these experiments the factors that affect the efficiency of utilization by dairy cattle of nitrogen from the usual protein and non-protein nitrogen sources, particularly roughages, have been studied with two obecjtives in mind:

1. To study the losses in the urine and the utilization of of nitrogen by lactating dairy cattle fed different levels and sources of protein and non-protein nitrogen.

2. To study the effects of various sources and amounts of energy in the ration on the efficiency of nitrogen utilization.

For the most part the data have been obtained during the period, 1953 through 1959, using a limited number of milking cows made available in the Ohio Agricultural Experiment Station herd especially for this purpose. Additional data have resulted from nitrogen metabolism studies carried out in conjunction with various projects in the Department of Dairy Science.

REVIEW OF LITERATURE

DETERMINING PROTEIN UTILIZATION OF DIFFERENT FEEDS

Practical feeding experiments and nitrogen balance studies are the common methods used for assessing the protein value of feeds. Feeding experiments have had the practical advantage, as far as milk production is concerned, of measuring the end results in terms of a salable product. The classical studies on protein requirements were made by this method (14, 25, 26). However they required a relatively long period of time an provided no information on the metabolism of protein.

In nitrogen balance experiments the nitrogen consumed in the feed is determined along with the output of nitrogen in the urine, feces, and milk in the case of lactating cows. These figures provide a measure of the nitrogen metabolism and may be used to compute digestibility and the efficiency with which nitrogen is used for productive purposes (12).

With simple stomached animals and calves the biological value derived from data obtained in nitrogen balance experiments generally measures the extent to which absorbed protein nitrogen is utilized by the animal (2, 42). With fully developed ruminants, measuring the biological value has less meaning although, some investigators have determined biological values for cattle and sheep (37). This requires the feeding of low-nitrogen rations which usually are not consumed readily by ruminants. In addition it is known that feeding protein free rations or rations low in protein content limits the growth and digestive action of rumen microorganisms (45), decreases the amount of protein recycled in salivary secretions (53), and results in an abnormal physiological state in the test animal which impairs health (25). For these reasons, and because fecal metabolic nitrogen and catabolic endogenous nitrogen are not biochemical entities which can be assayed (43, 44), reliable biological values for different kinds of protein cannot be obtained for dairy cattle. The appraisal of the value of proteins for dairy cattle has been limited to comparisons of actual quantitative results obtained in nitrogen balance experiments (37).

Critical levels of nitrogen intake must be used in nitrogen balance experiments when comparing the protein value of different kinds of feeds (4) and the results apply only for the physiological state of the animals used for the tests. On the other hand when protein is fed in excess of requirements, unused nitrogenous compounds absorbed into the blood are excreted in the urine along with catabolized tissue nitrogen (10, 26, 33). Thus nitrogen excreted in the urine is a useful tool for determining when and under what conditions excessive losses of nitrogen occur. It thereby serves as a measure of protein efficiency.

Evidence that urinary nitrogen varies markedly with level of protein feeding was shown by Perkins (53). He found that urinary excretion averaged 23.7 g. per day when low protein was fed compared to 228.6 g. per day when a high protein ration was fed. Conrad and Hibbs (6) found that calves receiving a 20 percent protein grain concentrate excreted 21.2 g. of total nitrogen daily compared to 16.7 g. excreted by calves receiving 14.5 percent protein in the grain concentrate. Hart and Humphrey (20, 21, 23) found an inverse relationship between the efficiency of nitrogen utilization and total urinary nitrogen. Similar results have been obtained by Morris and Wright (46, 47). Other results of Hart and Humphrey (19, 22) showed that the absorbed nitrogen of clover hay was utilized more efficiently than that from alfalfa hay. Whereas Maynard **et al.** (34) found no difference in the protein metabolism when timothy or clover hay was fed.

Protein digestibility increased with the level of protein in the ration (11), and nitrogen retention increased with the level of energy in the ration (29, 49).

NITROGEN METABOLISM IN THE RUMEN

Since the early work of Zuntz (64) and Hagemann (15), many investigators have studied utilization of non-protein nitrogen, particularly urea, in the rumen. They theorized, and set up experiments which demonstrated, that such readily available, less complex nitrogenous compounds could ultimately be transformed into useful nutrients by the symbiotic activity of rumen microorganisms. On the other hand, studies of protein metabolism in the rumen of natural feed stuffs are found in more recent reports.

These investigations fall naturally into the category of either non-protein nitrogen metabolism or protein metabolism in the rumen. They are discussed here under these topics.

Non-Protein Nitrogen:

The early investigations of the utilization of simple nitrogenous compounds for growing and lactating cattle were carried out in Europe. Krebs (**28**) has presented an extensive review of these early investigations and concluded that the data on nitrogen balances where protein was replaced by urea, ammonium salts and glycine were inconclusive because of the short period of the balances and because of both positive and negative results.

A series of reports from Wisconsin workers has added materially to our knowledge of non-protein nitrogen utilization in the rumen. Hart **et al.** (**18**) showed that growing calves could utilize urea and ammonium bicarbonate for growth and general tissue building. On an equivalent nitrogen basis urea was slightly more efficient. In repeating the experiments these authors showed that urea was utilized more efficiently for growth when a soluble sugar such as corn molasses was included in the ration. Fingerling **et al.** (9) and Harris and Mitchell (**24**) have confirmed these findings.

Urea may be efficiently used as the source of nitrogen in a maintenance ration to maintain nitrogen equilibrium (**24**).

The biological value of urea at nitrogen equilibrium on a maintenance ration was 62 compared to 79 for casein. Biological values from 34 to 74 have been reported which varied depending on the nature, energy content, of the ration and level of protein at which it was substituted.

The value of urea substitution for lactating cows is controversial. The early work of Schmidt and associates indicated that urea could substitute in part for crude protein but resulted in a more rapid decline in milk production (Reviewed by Krebs, **28**). Rupel **et al.** (**56**) reported that urea was satisfactory provided sufficient soluble carbohydrate was fed. Owen (50) found it to be an adequate substitute for blood meal in a milking ration. However, the work of Willett **et al.** (**62**) would indicate that urea is not a complete replacement for plant proteins for milk production. Archibald (**1**) found that Holstein cows produced 40.1 lbs. of milk daily when urea was fed in substitution for protein supplement at the rate of 3 percent of the grain mixture and

41.1 lbs. of milk daily when soybean oilmeal was fed on the same protein equivalent basis. Several experiments reported since are essentially in agreement with these results and suggest that urea used in dairy rations can replace protein supplements on a protein equivalent basis. However, it is noteworthy that, in those experiments (**24, 50**) where nitrogen excretion in the urine was determined, urea feeding resulted in a higher urinary nitrogen loss. This picture is consistent with the observations made by some investigators of lower weight gains in dairy cows fed urea continuously for one or more lactations (**1, 50**).

Rumen bacteria and protozoa are important factors in nitrogen utilization by dairy cattle. Johnson **et al.** (**27**) studied the nutritive value of bacterial protein in defaunated lambs fed urea and found the apparent digestibility to be 68.4 percent and the average daily retention of nitrogen to vary from 0.244 to 1.493 grams.

Loosli **et al.** (**32**) reported that goats and lambs were kept in positive nitrogen balance on a purified diet in which urea was the only source of nitrogen. These authors demonstrated conclusively, by balance trials and analyses of the rumen content, the synthesis (9 to 20-fold) of the ten essential amino acids for rat growth.

Careful analyses of dried rumen bacteria were made by McNaught **et al.** (**38**). Dried rumen bacteria contained, on a dry weight basis, 44.4 percent protein, 40.3 percent carbohydrate, 0.3 percent fiber, 3.1 percent lipid material, and 7.1 percent ash; the biological value was found to be 88.2 percent which compares favorably with dried milk protein. Their digestibility was 73.2 percent.

Some non-protein nitrogen compounds are broken down readily in the rumen to ammonia. Pearson and Smith (**51**) estimated that urea is hydrolyzed within an hour after entering the rumen of a cow. Wegner **et al,** (**60**) showed that urea was entirely converted to ammonia or protein nitrogen within one hour in a fistulated heifer. Protein hydrolysis to produce ammonia and synthesis of bacterial protein from ammonia occur simultaneously (**52**). The synthesis is augmented by a supplementation with starch or soluble carbohydrates such as maltose or molasses (**52, 59**). The increased synthesis of bacterial protein produced by urea supplementation is associated with an increased number of bacterial cells (**52, 59**). The crude protein in the rumen of a fistulated heifer increased and ammonia decreased with time only when starch was fed with the basal timothy hay ration. When the level of protein in the rumen was raised by casein supplements, the crude protein did not increase with urea feeding and the ammonia level did not decrease significantly with the passage of time (**40, 41, 61**).

One can derive from these experiments the conditions under which non-protein nitrogen is most efficiently used by all types of dairy cattle, that is, when the ration is low in protein and a source of carbohydrate other than cellulose is present.

Protein Metabolism in the Rumen: It has been shown by Miller and Morrison (39), based upon the results of 325 nitrogen balance studies with lambs, that plant proteins tended to have the same biological value and efficiency of nitrogen utilization regardless of their source. The constancy of these values has been cited as evidence that all the protein of the ration is eventually converted to microbial protein (37). This statement has been re-evaluated in the light of data obtained by Hamilton **et al.** (16) which indicated that this was true so long as the crude protein level did not exceed 12 percent and that at least one-sixth of the nitrogen is consumed as preformed protein.

It bears mentioning here that contrary to the majority of reports, Turk **et al.** (57) found very high biological values for alfalfa and clover protein. Lofgreen **et al.** (30) reported biological values of 71, 74, 76 and 80 for urea, urea plus methionine, linseed meal, and dried egg protein, respectively. Williams and Moir (63) obtained almost identical results in Australia.

A more decisive answer as to the amount of protein converted in the rumen to bacterial protein was obtained by McDonald (36). A sheep fitted with duodenal fistulas was fed a ration in which 82 percent of the protein was furnished as zein. By analyses of the protein passing through the duodenum, he calculated that 40 percent of the zein was converted to bacterial proteins.

Part of the food protein is converted to ammonia, absorbed through the rumen wall (35), and excreted into the urine. The rate of loss through absorption and excretion depends on fermentation rate in the rumen and solubility of the protein. A higher retention of nitrogen was observed by Cuthbertson and Chalmers (7) in sheep on a low plane of nutrition when they administered casein through a duodenal fistula than when the same amount was administered orally. However, losses due to deamination were sufficiently covered in well-fed animals. Basing an investigation on these observations, Chalmers and Synge (3) compared the nitrogen retained by sheep supplemented with herring meal and casein. Herring meal had the highest percent nitrogen retained and the lowest concentration of ammonia in the rumen.

Apparently the rapid rate of deamination of the casein protein can not be covered by microbial assimilation of the ammonia. Gray **et al.** (**13**), using disappearance from the forestomach as a criteria for measuring rumen nitrogen absorption, calculated that only 65 percent of the nitrogen of alfalfa hay fed with grain reached the abomasum, and as little as 48 percent when alfalfa hay alone was fed. The results of El-Shazley (**8**) suggest that protein solubility is the most important factor determining the rate of ammonia production in the rumen.

An experiment by McNaught **et al.** (**38**) studied the nutritive value of rumen bacterial and protozoal protein. They obtained digestibilities of 86.2 percent for protein of washed protozoa, 54.9 percent for protein as a crude mixture of rumen bacteria, 82.4 percent for the protein of a cultured rumen bacterium and biological values of 68, 66 and 41, respectively. When the digestibility of protozoal protein (86.2 percent) is compared to the 73.2 percent which they obtained for bacterial protein, it would appear that protozoa by engulfing bacteria and utilizing them for food may serve to make bacterial protein more available. Usuelli and Fiorni (**58**) reported increased weight gains of 46 percent on a basal ration, 57 percent when two grams of rumen bacteria were added daily, and 71 percent when two grams of rumen protozoa were added daily over a four week assay period to a chick diet.

EXPERIMENTAL RESULTS

Protein digestibility and nitrogen balance were determined in cows on various experimental regimes for 5, 7 or 10 day periods. The nitrogen content of the feed, feces, urine and milk was determined using the Kjeldahl method. In all cases fresh or refrigerated samples were used. Feces, urine and milk were analyzed without drying to avoid loss of nitrogen.

Feed was sampled for analysis when weighed in to each cow twice daily. Refused feed was weighed and sampled for analysis at the A.M. feeding.

In the experiments of 1954 specially constructed metabolism crates were used for the milking cows. A photograph of these crates is shown, Figure 1. Gooch tubing 3.5 inches in diameter, was used to channel urine into the collection bottles as described by Hansard (**17**). It was secured with rubber straps cemented with branding cement across the rump lateral to but parallel with the dorsal midline. See Figure 2. Ten to 14 days were allowed for the cows to adjust to the metabolism stalls. The procedure for collecting feces was changed after the first year because of the long adjustment period and because of the upset in physiological state of the cows in the metabolism stalls.

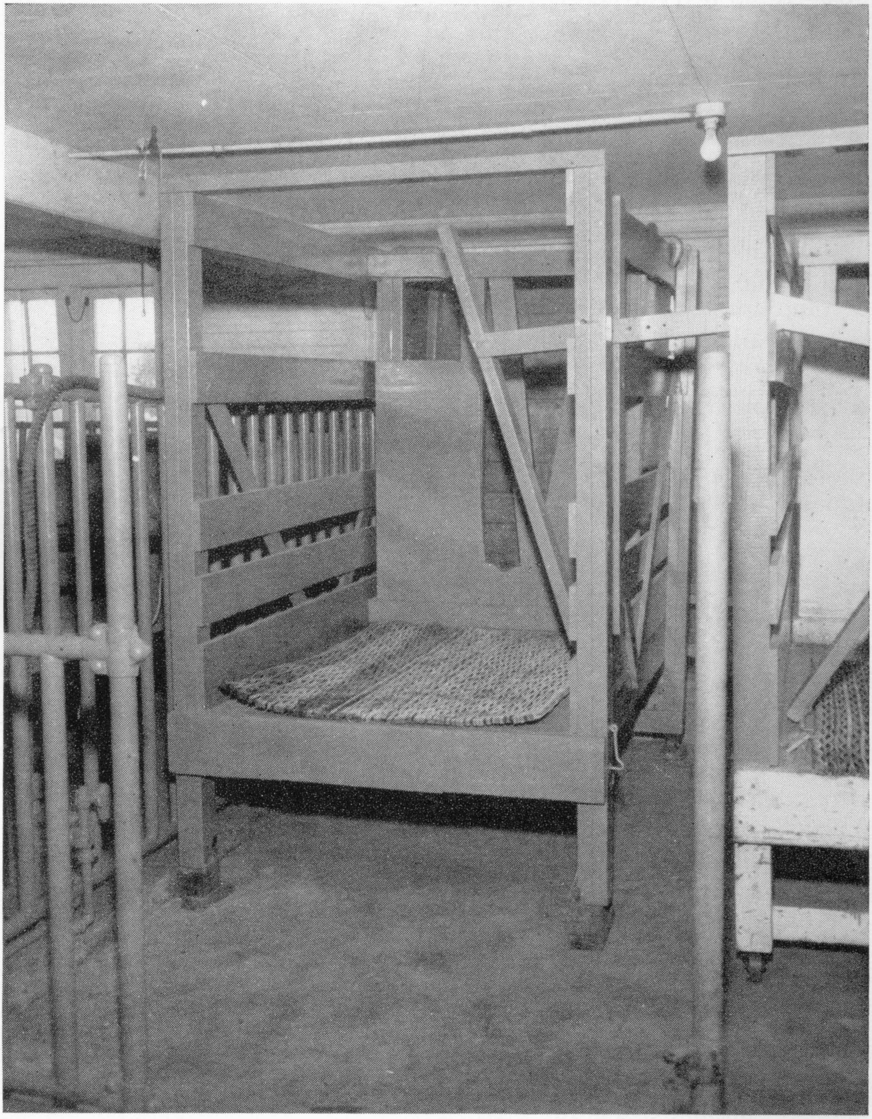

Fig. 1.—This photograph shows the metabolism crates that were used in the experiments conducted in 1954.

In experiments conducted during and after 1955, quantitative collection of urine and feces, milking, and measurement of feed intake were carried out in the stalls usually occupied by the cows in the milking barn. See Figure 3. The latter method of collecting urine and feces was facilitated by the use of rubber mats for cow beds, sisalkraft paper strips 4 × 5 feet on which the feces were collected, and the Gooch tubing attached to the cow as shown in Figure 2 and connected to a rubber bag of approximately 4 gallon capacity.

Electrical stall trainers were used to make the cows stand back for defecation. The rubber urine collection bags were emptied twice daily and the feces thoroughly mixed and sampled once daily. In subsequent experiments small mouthed metal milk pails were substituted for the rubber collection bags. This eliminated leaking from punctures occasionally encountered with the rubber bags.

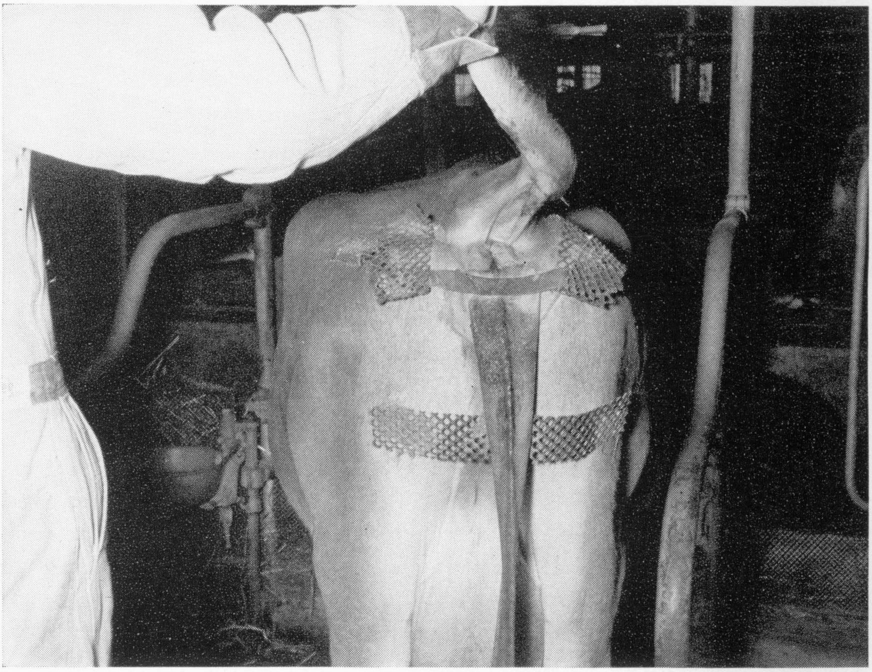

Fig. 2.—Gooch tubing was used to channel the urine into collection bottles. Rubber straps cemented with branding cement held the tubing.

Fig. 3.—In the experiments conducted in 1955 and later, the collection of urine, feces, milking and measurement of food intake was conducted in stalls in the dairy barn.

DESCRIPTION OF EXPERIMENTS AND RESULTS

EFFICIENCY OF NITROGEN UTILIZATION IN COWS FED DIFFERENT LEVELS OF PROTEIN IN THE GRAIN CONCENTRATE MIXTURE

Experiment 1

Six Jersey cows in late lactation were fed sulfur dioxide preserved grass silage free choice and the rate of grain concentrate feeding to each cow was held constant throughout the experiment. The amount of grain fed was based on milk yield at the beginning of the experiment and fed at the rate of one pound per three pounds of milk produced. The three concentrate mixtures used are shown, Table 1.

In the first phase of this experiment the 16 percent protein ration was fed to all 6 cows for a period of 3-weeks and a 10-day digestion and nitrogen balance trial was conducted. Then the cows were grouped

TABLE 1.—Composition of Grain Concentrate Mixtures Fed in Experiment 1

	Crude Protein Content, %		
	9%	16%	30%
Ground shelled corn, (lb.)	98	84	39
Soybean oil meal, (lb.)	–	14	59
Steamed bone meal, (lb.)	1	1	1
Iodized salt, (lb.)	1	1	1

into three pairs to equalize milk production. Each group was then assigned at random to one of the three rations shown in Table 1. After a three-week period the second 10-day digestion trial was carried out.

Protein digestibility, urine nitrogen, nitrogen balance, and efficiency of nitrogen utilization are shown in Table 2 for the two groups of digestion trials.

TABLE 2.—Protein Digestibility, Urine Nitrogen, Nitrogen Balance and Efficiency of Nitrogen Utilization in Cows Fed Three Different Levels of Protein in the Concentrate

Concentrate ration	Total protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency	
						Milk[1]	Nitrogen[2]
	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
1st digestion trial							
Group 1–16%	16 4	65 5	51 3	—15 7	21 2	32 9	14 2
Group 2–16%	16 4	63 4	38 9	+ 5 1	17 6	30 9	26 8
Group 3–16%	16 4	62 5	41 8	+ 9 5	19 4	28 3	21 2
2nd digestion trial							
Group 1– 9%	13 6	63 4	34 8	4 8	19 2	41 0	28 6
Group 2–16%	16 4	65 4	43 9	6 6	15 0	28 8	21 6
Group 3–30%	22 7	77 1	63 1	8 1	15 8	14 8	14 1

[1]Efficiency ofr milk production $= \frac{\text{nitrogen in milk}}{\text{net nitrogen absorbed}}$

[2]Total nitrogen efficiency $= \frac{\text{sum of nitrogen in milk} + \text{nitrogen stored}}{\text{nitrogen intake}}$

Experiment 2

The objective of the second experiment was to determine the efficiency of nitrogen utilization when low-protein grain concentrate rations were fed with high protein legume-grass silage as the only roughage. The silage contained 17.2 percent protein on the dry basis. Four cows, two groups of two cows each, in the first or second months of lactation were used for three balance trials on alternate weeks. Initially groups 1 and 2 were both fed the grain concentrate ration No. 1 shown in Table 3. After a two-week preliminary period the first balance trial

TABLE 3.—Composition of Grain Concentrate Rations, Experiment 2

	Ration 1	Ration 2	Ration 3
Ground shelled corn	500	550	600
Ground whole oats	300	300	300
Soybean oil meal	100	50	----
Steamed bone meal	9	9	9
Iodized salt	9	9	9

TABLE 4.—Efficiency of Nitrogen Utilization in Cows Fed Low Protein Content Concentrates With High Protein Legume-Grass Silage

Concentrate rations	Protein in the ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
						Milk	Total
	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Trial I							
14 % protein, group 1	15.9	64.8	48.9	—12.8	26.0	34.4	22.6
14 % protein, group 2	15.9	66.8	45.6	— 7.8	32.4	35.8	21.1
Trial II							
14 % protein, group 1	15.9	70.8	41.5	+21.6	27.5	31.1	39.6
12.5 % protein, group 2	15.5	63.5	39.9	— 6.0	33.2	40.4	23.6
Trial III							
14 % protein, group 1	15.9	71.8	43.2	+16.8	26.3	32.1	28.3
11.5 % protein, group 2	15 1	66.7	41.1	+ 3.9	31.5	37.1	27.1

was carried out. During the second balance trial group 2 was fed ration No. 2. Ration No. 3 was fed in the third trial period to group 2. Group 1 was fed ration No. 1, the control ration, throughout the three balance trials.

Results showing the average protein digestibility, urine nitrogen, nitrogen balance, milk production and efficiency of nitrogen utilization are shown, Table 4.

EFFICIENCY OF NITROGEN UTILIZATION IN COWS FED DIFFERENT AMOUNTS OF GRAIN CONCENTRATE

Experiment 3

This experiment was planned to make preliminary observations on the nitrogen metabolism of cows after removing the grain from rations containing mostly forage crop silage. Two Jersey cows were used in a series of five digestion and nitrogen balance trials carried out on alternate weeks. At the beginning of the first trial the cows were consuming 8 pounds of clover hay, 6 pounds of grain concentrate (12 percent total protein), and 40 to 50 pounds of forage crop silage. Each cow was fed silage made from forage from the same fields but preserved differently. One silage had been preserved with 8 pounds of SO_2 gas per ton and the other with 150 pounds of ground ear corn per ton of green material.

Grain feeding was terminated after the first digestion trial and after a two week period the second pair of digestion trials were carried out. In the third trial the clover hay was taken out of the ration and the comparison of sulfur dioxide and corn-preserved legume-grass silage fed free choice was made without grain supplementation. In the fourth trial the type of silage fed the two cows was reversed. In the final experiment both cows were fed sulfur dioxide preserved silage with 6 pounds grain concentrate (18 percent total protein).

The feeding regimes used and the results obtained in this experiment are presented in Table 5.

Experiment 4

The nitrogen metabolism phase of this experiment was done in order to obtain further data on the effects of various levels of grain feeding. The study was carried out in conjunction with an experiment set up for determining the milk production response to feeding meadow crop silage versus freshly chopped green forage (soilage) when fed with different levels of grain.

A 2 × 3 factorial design was used with the following blocks:

Block 1—Silage with no grain
" 2—Silage with one-half grain

TABLE 5.—The Effect of Removing and Adding Grain Concentrate in the Rations of Cows Fed Sulfur Dioxide and Corn-Preserved Grass Silage on Milk Production and Efficiency of Nitrogen Utilization

Cow No.	Trial No.	Ration	Silage preservative	Protein in the ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficienry of nitrogen utilization: Milk	Total
				(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
10	1	Sil., Cl.-hay, Grain	Corn	13.5	57.9	31.3	— 8.5	20.8	52.5	26.6
14	1	Sil., Cl.-hay, Grain	SO_2	13.0	59.2	39.7	—12.8	17.9	43.2	19.5
10	2	Sil., Cl.-hay	Corn	13.2	50.2	34.4	—26.1	16.9	52.0	15.8
14	2	Sil., Cl.-hay	SO_2	12.3	51.9	41.0	—28.1	14.7	45.4	10.9
10	3	Silage	Corn	11.5	58.6	30.0	+28.3	14.0	49.1	28.6
14	3	Silage	SO_2	12.0	64.5	34.8	+10.7	12.9	39.3	29.7
10	4	Silage	SO_2	12.0	58.8	37.8	—11.3	13.9	40.4	21.0
14	4	Silage	Corn	11.5	57.7	25.4	+11.4	16.3	56.2	32.3
10	5	Silage, Grain	SO_2	12.9	67.6	33.8	+20.4	16.6	52.7	33.8
14	5	Silage, Grain	SO_2	12.9	70.4	36.5	+21.9	17.3	50.0	33.9
Av.	1-4		SO_2	12.4	58.6		—10.4	14.9	42.1	20.3
Av.	1-4		Corn	12.4	56.1		+ 1.3	17.0	52.5	25.8

" 3—Silage with full grain
" 4—Soilage with no grain
" 5—Soilage with one-half grain
" 6—Soilage with full grain

One Jersey cow from each block of 5 animals was used for five-day digestion and nitrogen balance trials. The cows in the one-half grain blocks were fed 0.2 pound of grain daily per pound of milk over 12 pounds. The cows in the full grain blocks were fed 0.4 pound of grain daily per pound of milk over 12 pounds.

In 1957 two trials were carried out during the second and fourth week of the summer feeding period. In 1958 a series of five digestion and nitrogen balances was completed starting with the second week of feeding and at four-week intervals thereafter through the summer. The soilage was chopped twice daily and sampled at the time of feeding. In the early summer, silage from the previous year was used whereas the first cutting from the same year was used during the last part of the summer. The grain concentrate was composed of 66 percent corn and cob meal, 35 percent ground whole oats and 1 percent iodized salt.

Results for the 1957 and 1958 experiments are presented in Tables 6 and 7 respectively.

TABLE 6.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Meadow Crop Silage or Soilage With Different Levels of Grain Concentrate (1957)

Roughage used	Amount of grain	No. of trials	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization: Milk	Efficiency of nitrogen utilization: Total
			(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Soilage	None	2	23.8	78.6	33.0	47.8	23.4	19.2	31.6
Soilage	One-half*	2	21.0	75.8	35.2	85.7	32.9	24.9	39.8
Soilage	Full*	2	19.7	74.0	33.5	87.0	28.7	24.5	40.5
Silage	None	2	18.0	63.6	49.0	—17.2	23.8	36.1	13.8
Silage	One-half*	2	16.5	65.6	43.8	16.1	19.4	30.6	26.3
Silage	Full*	2	15.5	63.5	31.6	19.8	22.7	37.2	31.9

*Cows in groups receiving a "full" feed of grain were fed at the rate of 0.5 pound of grain per pound of milk produced above 12 pounds for Jerseys and 0.4 pound of grain per pound of milk produced above 20 pounds for Holsteins. One-half grain groups received grain at one-half the rate fed the full grain group.

TABLE 7.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Meadow Crop Soilage or Silage With Different Levels of Grain Concentrate (1958)

Roughage used	Amount of grain	No. of trials	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization: Milk	Efficiency of nitrogen utilization: Total
			(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Soilage	None	5	19.8	73.2	44.6	41.6	26.1	25.2	28.7
Soilage	One-half*	5	17.9	72.6	36.4	66.6	40.7	30.2	36.1
Soilage	Full*	5	17.5	71.2	37.3	55.6	28.6	28.4	33.9
Silage	None	5	16.3	63.0	42.2	5.2	17.2	30.3	20.7
Silage	One-half*	5	15.5	64.2	37.4	25.2	28.5	31.2	27.6
Silage	Full*	5	15.2	65.0	34.5	16.5	23.4	31.7	28.8

*Cows in groups receiving a "full" feed of grain were fed at the rate of 0.5 pound of grain per pound of milk produced above 12 pounds for Jerseys and 0.4 pound of grain per pound of milk produced above 20 pounds for Holsteins. One-half grain groups received grain at one-half the rate fed the full grain group.

Experiment 5

In this experiment the effect of the roughage-to-grain ratio fed on the efficiency of nitrogen utilization was studied. Four cows which had been adjusted to legume-grass silage feeding over a 2-month period were divided into groups of two and fed either a 3:1 or 2:1 ratio of roughage to grain. After a two-week period, the first in a series of two digestion and nitrogen balance trials was begun. The legume-grass silage, predominantly alfalfa, had been ensiled after wilting. The amount of silage fed was varied according to the appetite of the individual cows and the amount of grain fed within each group was adjusted daily to maintain a constant ratio of hay (dry roughage) to grain. The only exception being that the quantity of silage and grain fed were held constant during the feces collection periods. Later second cutting alfalfa hay was used to replace all of the legume-grass silage in the ration but the two ratios of hay to grain (2:1 and 3:1) were maintained. The digestion and nitrogen balance trials were conducted during the first and fifth week after alfalfa hay feeding was started.

The grain ration fed in both experiments was composed of: 450 pounds of corn, 300 pounds of oats, 100 pounds of wheat bran, 50 pounds of soybean oil meal, 10 pounds of salt and 10 pounds of bonemeal.

The data showing efficiency of nitrogen utilization and milk production for the two ratios of roughage to grain are shown in Table 8.

TABLE 8.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed 2:1 or 3:1 Ratio Roughage (Dry Matter) to Grain With Legume-Grass Silage or Alfalfa Hay

Roughage used	Hay:Grain ratio	No. of trials	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
								Milk	Total
			(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Legume-grass silage	3:1	4	16.9	68.7	42.0	31.2	19.8	22.5	21.5
Legume-grass silage	2:1	4	16.8	69.9	46.0	16.7	23.9	27.4	23.9
Alfalfa hay	3:1	4	15.7	69.7	39.2	21.9	20.9	20.9	30.4
Alfalfa hay	2:1	4	15.4	66.9	38.4	20.0	25.5	25.5	25.9

EFFICIENCY OF NITROGEN UTILIZATION IN COWS FED ROUGHAGES CONTAINING DIFFERENT PERCENTAGES OF TOTAL PROTEIN

Experiment 6

The objective of this experiment was to determine the efficiency of nitrogen utilization when legume-grass silage and hay were fed in different proportions. The nitrogen metabolism studies were carried out in conjunction with feeding trials involving a total of 48 cows over a period of three years. Grain was fed throughout the experiment in proportion to the amount of roughage consumed (3:1 ratio). The grain concentrate ration used was composed of: 450 pounds of corn, 300 pounds of oats, 100 pounds of wheat bran, 50 pounds of soybean oil meal and 10 pounds of salt. The amounts of silage and hay fed, protein content of the roughages used, and the year in which the experiments were conducted are shown in Table 9.

TABLE 9.—Proportions of Hay and Silage and Protein Content of the Roughages Fed in Experiment 6

Year	Silage	Hay	Protein Content
	(%)	(%)	(%)
1954	100	0	11.1
1954	80	20	11.1
1954	50	50	11.1
1955	50	50	13.6
1955	20	80	13.8
1955	0	100	13.9
1956	100	0	15.5
1956	50	50	15.1
1956	0	100	14.7

The protein digestion and nitrogen balance trials were carried out in the third and fourth month of lactation during the fourth and sixth week of the 16-week feeding period. The results of these trials are presented, Table 10.

TABLE 10.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Various Proportions of Legume-Grass Hay and Silage Containing Percentages of Total Protein*

Silage in ration	Hay in ration	Protein in roughage	No. of trials	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
									Milk	Total
(%)	(%)	(%)		(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
100	0	11.1	3	11.6	64.3	33.5	6.7	21.4	42.6	30.4
80	20	11.1	3	11.6	64.1	36.0	10.4	20.3	36.1	28.2
50	50	11.1	3	11.6	63.0	37.7	3.0	22.0	38.8	25.3
50	50	13.6	4	13.6	68.2	45.1	1.8	27.7	37.6	23.8
20	80	13.8	4	13.7	69.4	42.7	2.7	26.6	36.9	26.1
0	100	13.9	4	13.7	64.4	44.2	—20.5	31.6	42.6	22.9
100	0	15.5	2	14.8	56.4	30.2	22.1	21.6	37.4	29.4
50	50	15.1	2	14.5	63.8	28.0	48.7	32.5	33.6	35.7
0	100	14.7	2	14.2	69.0	39.5	23.8	21.9	31.5	30.6

*Grain fed in proportion to roughage consumed; 3:1 ratio of roughage (dry basis) to grain used.

Experiment 7

This experiment represents a preliminary effort to evaluate the effect of pelleting high protein hay on efficiency of nitrogen utilization.

Third growth field chopped alfalfa was dehydrated, passed through a hammer mill without a screen, and pelleted through a ¾ inch round die. The alfalfa hay pellets were fed free choice to six Jersey cows for a six-week period. Three pounds of clover hay was fed daily for the first four weeks. Four cows were then continued on three pounds of clover hay while the remaining two cows were fed pellets as the only roughage from four to six weeks. Two other cows were fed third growth long alfalfa hay of similar maturity and protein content. Grain intake was held constant with respect to roughage consumption and fed at the rate of one part grain for each three parts roughage consumed. The formula for the grain mixture used was 600 pounds of corn, 300 pounds of oats, 100 pounds of soybean meal, 10 pounds of bonemeal and 10 pounds of iodized salt.

Seven-day digestibility and nitrogen balance trials were carried out during the last week of the feeding trials. The results are shown in Table 11. Also shown are the results from two of same cows which were fed soilage in Experiment 4.

TABLE 11.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Third Growth Alfalfa Hay in the Pelleted or Long Cut Form*

Roughage used	No. of trials	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
							Milk	Total
		(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Long hay	2	18.5	73.5	35.4	104.6	21.3	16.6	38.1
Pellets	2	20.0	66.4	39.3	51.6	23.1	22.5	27.1
Pellets + 3 lb. of hay	4	19.2	64.2	38.8	39.8	23.4	24.6	25.5
Soilage	2	19.0	76.1	35.7	102.1	28.6	21.2	40.2

*Grain fed in proportion to roughage consumed; 3:1 ratio of hay (dry basis) to grain used.

THE EFFICIENCY OF NITROGEN UTILIZATION IN DAIRY COWS FED CORN SILAGE, CORN-PRESERVED LEGUME-GRASS SILAGE OR WILTED LEGUME-GRASS SILAGE

Experiment 8

Four Jersey cows in the latter stages of their lactation periods were placed on corn silage and alfalfa hay for a 2-week period. They were then changed to corn-preserved (150 pounds of corn and cob meal per ton of green material) wilted legume-grass silage for a six-week period. Feed intake and milk production were measured while each type of silage was fed. Five-day digestion and nitrogen balances were carried out during the second week of the corn silage feeding period and the first, third and sixth week of corn-preserved grass-legume silage feeding period. Results showing the efficiency of nitrogen utilization are presented in Table 12.

Experiment 9

This experiment was done to compare nitrogen utilization in cows fed corn silage followed by wilted legume-grass silage. Two Jersey and two Guernsey cows were allowed to consume corn silage and alfalfa free choice on the dry basis of a 2:1 ratio for a period of seven weeks. The corn silage was then replaced with legume-grass silage and the 2:1 ratio of silage to hay was continued for an additional five-week period. The alfalfa hay contained 20 to 30 percent grass. A 16 percent protein grain mixture was fed according to milk production and amounted to approximately one-third of the dry feed intake. Daily feed intake and milk production records were kept.

TABLE 12.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Corn Silage or Legume-Grass Silage As All or Part of the Roughage Ration

Roughage used	No. of trials	Grain in ration	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
								Milk	Total
		(%)	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Experiment 8									
Corn silage + hay	4	36.0	9.9	56.1	40.4	—20.7	17.5	50.1	16.0
Legume – grass silage (corn preserved)	12	39.5	15.5	66.7	41.2	25.8	17.4	25.0	25.4
Experiment 9									
Corn silage + hay	12	50.0	12.9	66.4	30.4	16.8	26.4	43.7	36.1
Legume – grass silage + hay	12	32.0	14.5	71.7	33.1	29.0	21.9	30.3	33.8

Digestibility and nitrogen balances were determined at two-week intervals during the second, fourth and sixth weeks of the corn silage feeding period and during the first, third nd fifth week of the legume-grass silage feeding period using five-day collection periods.

The results of this experiment are shown in Table 12 also.

Experiment 10

In this experiment nitrogen utilization was studied in dairy cows which were fed half of their roughage dry matter as corn silage and one-half as legume-grass silage compared to both wilted and corn-preserved legume-grass silage. One group of two cows was fed one-half corn silage and one-half wilted legume-grass silage on a free choice basis for an eight-week period while a second group of two cows received the legume-grass silage as the only roughage. Grain was fed at the rate of one part grain to two parts dry roughage. The grain fraction of the corn silage (estimated to be 37 percent of the dry weight) was considered as part of the grain. The same cows were used to repeat the experiment except corn-preserved legume-grass silage was used in place of the wilted legume-grass silage. The legume-grass silage had been preserved with 200 pounds of corn and cob meal per ton of green material.

The 2:1 ratio of roughage to grain was maintained, with the grain fractions of the corn silage and of the corn-preserved, grass-legume silage estimated and included in the one part grain.

Digestion and nitrogen balance trials were carried out at the conclusion of each feeding experiment. The results are presented in Table 13.

TABLE 13.—The Efficiency of Nitrogen Utilization in Dairy Cows Fed Corn Silage as One-Half of the Total Roughage Fed

Roughage used	Grain in ration	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
							Milk	Total
	(%)	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Legume-grass silage	33.3	17.3	67.6	46.7	0.0	24.8	30.7	20.8
Corn silage + legume-grass silage	36.0	15.2	63.8	38.6	—13.2	20.0	34.9	18.3
Corn-preserved legume-grass	31.8	15.3	68.3	38.1	26.1	19.4	30.8	30.1
Corn silage + corn preserved legume-grass silage	34.2	15.0	64.7	39.6	9.1	15.6	32.4	25.1

Experiment 11

In this experiment the efficiency of nitrogen utilization was determined in cows fed legume-grass silage and corn and cob meal in a 3:1 ratio of dry roughage to grain. The purpose was to determine the effect of fermentation on the value of corn for stimulating nitrogen utilization. One group of two cows was fed free choice silage to which corn and cob meal was added to the green material previous to ensiling. To the second group of two cows corn and cob meal was fed twice daily with free choice wilted legume-grass silage. A third group was fed free choice silage and a grain mixture containing 13 percent total protein at the rate of three parts dry roughage to one part grain. The same forage crop was used for making the silage fed to all three groups. During the eighth week of the feeding period digestion and nitrogen balance trials were carried out. The results of these trials are shown in Table 14.

TABLE 14.—Efficiency of Nitrogen Utilization in Cows Fed Legume-Grass Silage With Corn and Cob Meal Added Before Ensiling or at the Time of Feeding

Rations used	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
						Milk	Total
	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Corn and cob preserved legume-grass silage	9.9	55 7	27.9	— 6.8	22.7	59.1	27.7
Legume-grass silage + corn and cob meal	12.3	63.5	32.4	13.6	18.6	37.4	31.0
Legume-grass silage + grain (12% protein)	13.5	67.8	35.9	22.7	23.3	34.8	31 9

DISCUSSION OF RESULTS

The results show that the amount of nitrogen used by lactating dairy cows was influenced by several factors including the nitrogen content of the rations, the type of forage fed, the digestible dry matter intake per unit body weight and the inclusion of grain in the ration. However, these factors did not always produce straight line effects and differed among roughages. With legume-grass silage as the roughage in experiments 1 and 2, Tables 2 and 4, nitrogen efficiency appeared to decline at a decreasing rate when the protein content of the grain mixture was increased by replacing corn meal with soybean oil meal.

In order to obtain a more complete picture of this relationship of the average efficiency of nitrogen utilization of all groups of cows fed legume-grass silage that were found to be in positive nitrogen balance were plotted against the percentage of total protein in the ration, Figure 4. These data indicated a very slight increase in efficiency with increased percentage of protein to approximately 15 percent. Beyond 15 percent protein there was a rapid decrease which followed a logarithmic curve.

It is likely that the progressive decrease in efficiency was caused by the relatively large amounts of non-protein nitrogen (NPN) present in the legume-grass silages, as has been observed in rations containing urea in amounts above 12 percent protein equivalent (24). Our analyses

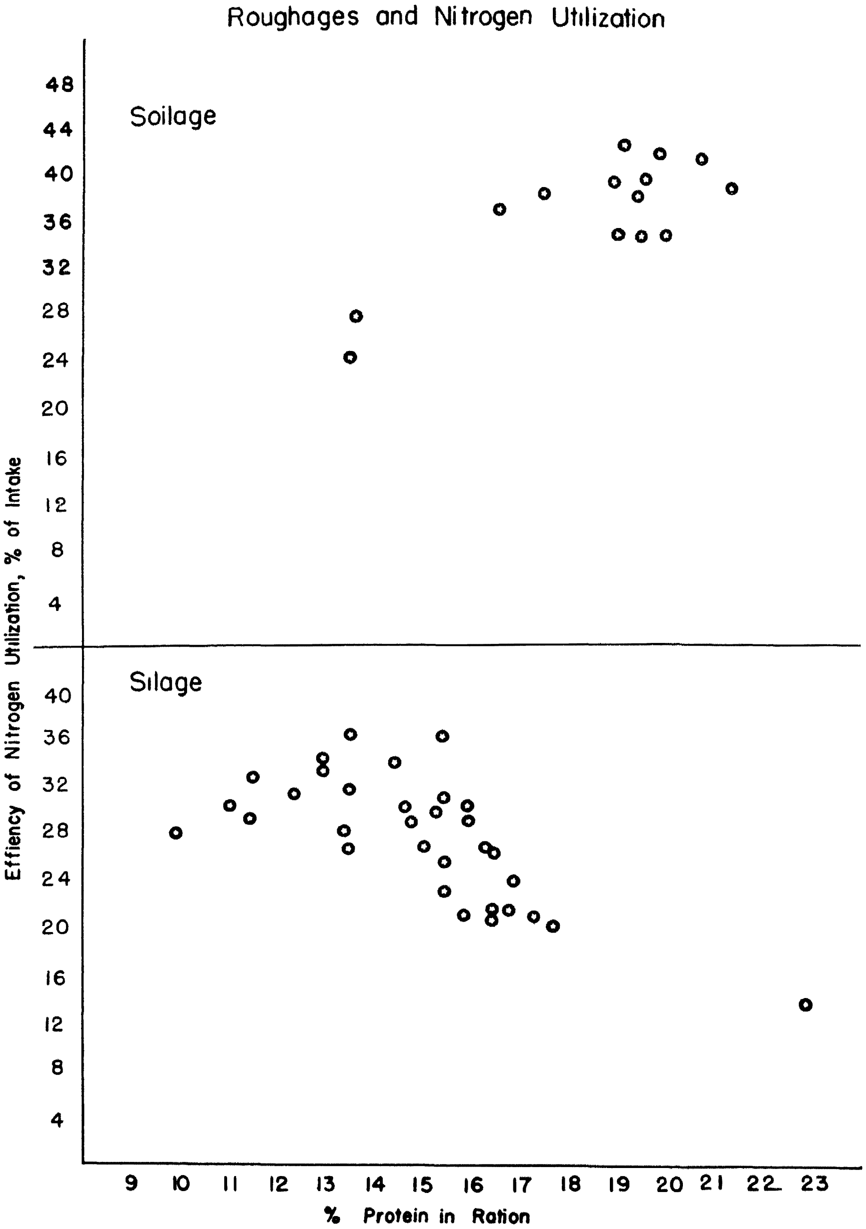

Fig. 4.—In this chart, the average efficiency of nitrogen utilization of all groups of cows fed grass-legume silage that were in positive nitrogen balance were plotted against the percentage of total protein in the ration.

for TCA soluble nitrogen showed that NPN ranged from 25 to 46 percent of the total forage nitrogen compared to 15 to 18 percent in hay and fresh forages, appendix, Table 1. However, this is confounded with variation in total nitrogen content of the ration and an insignificant regression coefficient, b = .005, was obtained for efficiency of nitrogen utilization regressed on percent NPN.

The percentage apparent digestibility of nitrogen was unrelated to efficiency. This is in contrast to the results of French **et al.** (11) who studied rations with lower percentages of total protein.

TABLE 15.—The Efficiency of Nitrogen Utilization in Dairy Cows at Nitrogen Balance When Various Forages Were Fed

Rations used	Protein in ration	Protein digested	Urine nitrogen	Nitrogen balance	Milk production	Efficiency of nitrogen utilization	
						Milk	Total
	(%)	(%)	(%)	(g./d.)	(lb./d.)	(%)	(%)
Corn and cob preserved legume-grass silage	14.3	64.2	38.4	1.1	23.5	40.1	26.5
Corn and cob preserved legume-grass silage	9.9	57.1	28.8	1.9	19.5	47.5	28.2
Av.	12.1	60.7	33.6	1.5	21.5	43.8	27.3
Legume-grass silage	14.8	56.7	35.0	0.0	16.9	39.4	21.4
Legume-grass silage	15.3	59.6	40.8	0.9	20.2	32.2	18.8
Legume-grass silage	15.4	64.9	41.7	6.3	18.8	31.3	22.2
Legume-grass silage	17.5	68.5	52.0	3.6	22.2	26.1	16.6
Legume-grass silage	18.3	63.3	40.5	— 3.9	18.7	39.1	22.8
Av.	16.3	62.6	42.0	1.4	19.3	33.6	20.3
Soilage	13.7	62.1	34.6	0.0	40.7	44.3	27.5
Soilage	13.5	59.6	35.5	— 6.3	29.2	44.6	24.1
Av.	13.6	60.8	35.0	— 3.2	35.0	44.4	25.2
Corn silage + hay	9.7	59.3	29.4	5.6	17.7	46.2	31.4
Corn silage + hay	12.7	64.8	38.4	1.9	19.8	39.5	26.4
Corn silage + hay	12.4	63.3	31.5	3.6	25 6	47.4	31.7
Corn silage + hay	12.4	65.0	31.5	1.7	26.4	49.8	33.5
Corn silage + hay	12.4	62.3	40.1	— 1.1	17.7	36.7	22.6
Corn silage + hay	12.4	62.9	28.0	— 4.4	33.2	58.4	35.0
Av.	12.0	63.3	33.2	1.2	23.4	46.3	30.1

All through the entire group of experiments nitrogen efficiency was usually less in cows fed legume-grass silage. Since critical levels of nitrogen intake must be used when comparing the nitrogen value of different feeds, results from cows with nitrogen balances between (+ or —) 6 grams per day were tabulated in accordance with the type of forage fed, Table 15. Not only was the efficiency of total nitrogen utilization 5 to 10 percentage units less than for other types of forages but the average efficiency with which absorbed nitrogen was used for milk production was also less.

In contrast, the nitrogen of fresh-cut legume-grass without grain was utilized more efficiently for both body retention and milk nitrogen, Tables 6, 7 and 15. Even with grain the efficiency of total nitrogen utilization remained essentially constant as the level of protein in the ration increased above 15 percent, (Figure 4). This is of considerable nutritional importance and is contrary to presently accepted theory on the physiology of nitrogen metabolism (33).

The results presented in Tables 6 and 7 show that the cows fed fresh cut meadow crops stored high amounts of nitrogen on the daily basis even though some cows were in early lactation. This higher storage coincided with their observed higher weight gains (54). The physiological importance to the cow of replenishing the nitrogen lost through catabolism of tissue during the early part of lactation merits further research. It is noteworthy that freshly-cut legume-grass mixtures accelerated this process whereas legume-grass silage diminished or prevented it.

Urine losses, measured as the percent of intake nitrogen excreted, increased directly as the nitrogen content of the ration increased when legume-grass silage was fed as the only roughage, Figure 5. The regression showed that an average of 2.8 percent of the intake nitrogen was lost for each increment increase of 1 percent in the total protein of the ration. With freshly-cut forage the percentage of urine losses were relatively low and unrelated to the total protein content of the ration. Even though the quantity of urine nitrogen increased with increased nitrogen in the ration with all types of forages. (Appendix, Table 2), the percentage seems to have remained unaffected, Figure 5. This observation is in line with the results on total nitrogen efficiency.

The most significant observation in this study relating to energy needs for sufficient nitrogen utilization was the finding that the differences in digested dry matter intake per animal unit accounted for most of the variation in quantity of nitrogen used for milk and tissue storage,

Figure 6. This means that high nitrogen utilization is principally a matter of high feed intake provided the nitrogen is available in the ration.

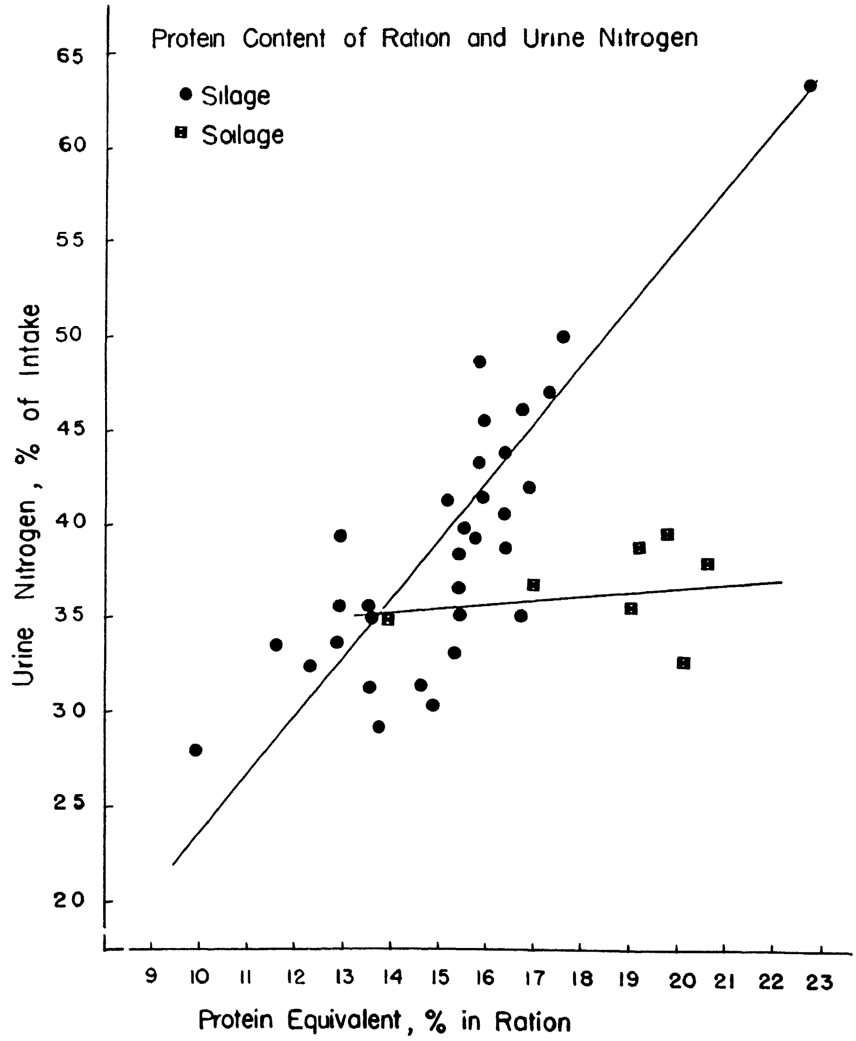

Fig. 5.—It was shown that urine losses, measured as the percent of intake nitrogen excreted, increased directly as the nitrogen content of the ration increased when grass-legume silage was fed as the only roughage.

Again the freshly-cut forage appeared advantageous in comparison to ensiled forage. The productive nitrogen expressed as protein per pound of increase in digestible dry matter was 0.20 pound for the fresh-cut forage compared to 0.12 pound for ensiled forage.

To augment the results in these experiments, data were taken from experiments reported in the literature which had been collected on cows under carefully described conditions. These data were compared on the basis of the different roughages used and only data from animals which were near nitrogen balance, e.g. ± 6 grams, were included. These comparisons are summarized in Table 16. They show further

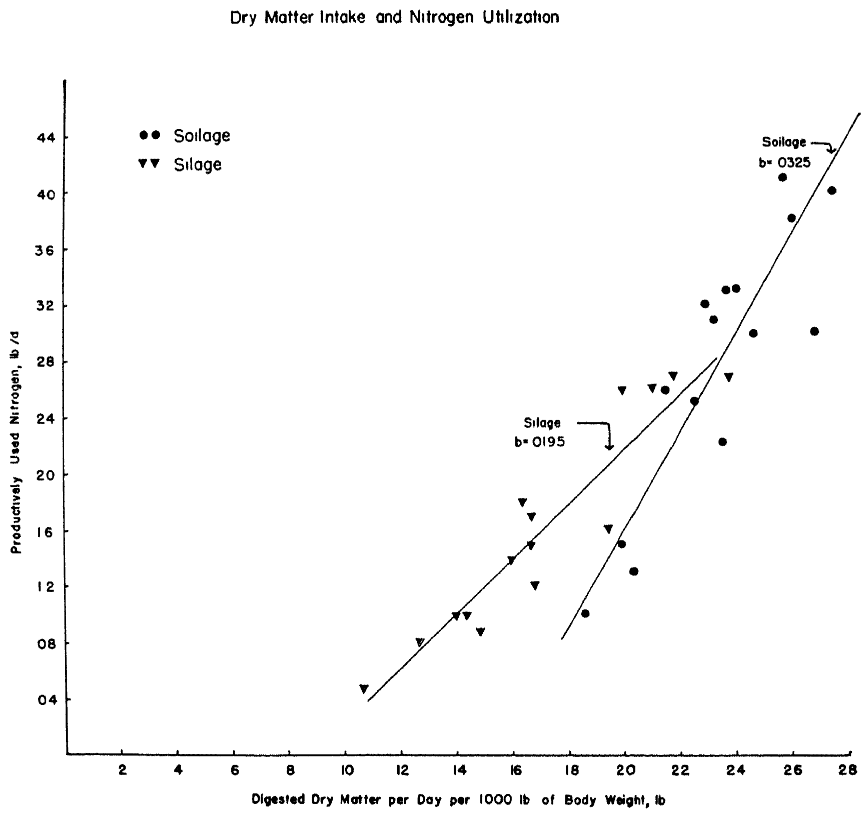

Fig. 6.—The differences in digested dry matter intake per animal unit accounted for most of the variation in quantity of nitrogen used for milk and tissue storage.

TABLE 16.—Efficiency of Nitrogen Utilization in Dairy Cattle Fed Various Roughages Comparisons With Data from the Literature

Roughage Fed	Supplemental Ration	Nitrogen Metabolism					Nitrogen Efficiency		Source of Data
		In-take	Di-gested	Urine	Milk	Balance	Milk	Total	
		(lb./d.)	(%)	(%)	(lb./d.)	(g./d.)	(%)	(%)	
Legume-grass silage	Cereal grain	.50	62.6	42.0	.09	+1.4	33.6	20.3	Table 15
Legume-grass soilage	Cereal grain	.62	60.8	35.0	.17	—3.2	44.4	25 8	Table 15
Spring dried grass	Straw, beet pulp, oats	.49	56.0	24.5	.15	+0.5	56.3	31.1	Morris **et al. (47)**
Autumn dried grass	Straw, beet pulp, oats	.45	61.0	33.3	.15	+2.5	45.3	29.0	Morris **et al. (47)**
Grass silage	Straw, beet pulp, oats	.40	54.0	22.5	.12	+0.2	55.5	32.1	Morris **et al. (47)**
Clover hay + corn silage	Cereal grain and oil meal	.57	56.0	22.8	.17	0.0	54.5	30.1	Maynard **et al. (34)**
Timothy hay + corn silage	Cereal grain and oil meal	.49	59.4	24.4	.17	+0.8	60.2	34.7	Maynard **et al. (34)**
Corn stover	Gluten feed + corn meal	.35	63.2	31.4	.11	—3.5	50.2	30.9	Hart and Humphrey **(21)**
Alfalfa hay	Corn starch	.33	62.1	33.3	.09	—0.1	33.2	28.3	Hart and Humphrey **(19)**
Clover hay + corn silage	Corn meal and oil meal	.37	56.4	18.9	.13	+1.6	63.0	36.0	Hart and Humphrey **(22)**
Alfalfa hay + corn silage	Cereal grain and cottonseed meal	.40	60.7	27.5	.13	—2.6	54.4	31.2	Hart and Humphrey **(23)**
Alfalfa hay + corn silage	Cereal grain and soybean meal	.46	63.3	33.2	.14	+1.2	46.3	30.1	Table 15

that the efficiency of nitrogen utilization was uncommonly low for legume-grass silage compared to soilage, dried grass, clover hay and corn silage, alfalfa hay and corn silage.

In addition roughage rations containing large amounts of alfalfa resulted in less efficient nitrogen utilization than when the major forage furnishing nitrogen was either grass or clover. This is in agreement with other results obtained with young calves (**6**). Also, this is in line with the observation of the relatively rapid breakdown of alfalfa protein in the rumen (**5, 13**) and losses of relatively large amounts by direct absorption through the rumen wall (35). Whether or not a significant amount of the non-protein nitrogen from legume-grass silage is lost by direct absorption through the rumen wall is yet to be determined.

The addition of cereal grain to an all forage ration increased efficiency of nitrogen utilization markedly while decreasing urine losses, Tables 5, 6 and 7. It is noteworthy that grain additions (ground corn and oats) had a qualitative effect only on the nitrogen metabolism. Inspection of Appendix Table 2 and Tables 5 and 6 shows that cows fed at the one-half grain level, where grain intake ranged from approximately 10 to 23 percent, utilized nitrogen as well as cows fed on a full grain regime. Cows fed grain had slightly higher apparent nitrogen digestion coefficients. Presumably this was due to increased ruminal synthesis. Furthermore, nitrogen utilization for all nitrogen uses or milk production in cows fed the 3:1 ratio of roughage to grain was equally as efficient as in cows fed a 2:1 ratio, Experiment 5, Table 3.

It was interesting to learn what effect each known variable had on nitrogen metabolism independent of all other variables. The independent effects of lactation, digestible dry matter intake per 1000 pounds of body weight, total nitrogen intake, grain feeding, and type of forage fed on milk nitrogen, urine nitrogen and efficiencies were assessed by computing a multiple regression on silage and soilage plus hay data. The regression coefficients and means are shown in Table 17. This analysis shows that the predominant influences on efficiency were digestible dry matter intake for silage and nitrogen intake for the hay and soilage combined. There was no effect of lactation on nitrogen efficiency in these experiments, where most of these cows were between 2 and 7 months of lactation. However, there was a significant negative correlation between milk nitrogen and lactation as was expected.

If capacity to utilize nitrogen for milk and storage with increased intake of digestible dry matter is an acceptable criterion for establishing

TABLE 17.—Multiple Regression Analysis[1]. Independent Effects of Dry Matter Intake, Stage of Lactation, Nitrogen Intake, and Grain on Milk Nitrogen, Urine Nitrogen and Efficiency

	Dry matter	Lactation stage	Nitrogen	Grain	Mean	R^2
	(lb./1000)	(d.)	(lb.)	(Present=1 or Absent=0)	(y)	
SOILAGE AND HAY						
Mean (x)	22.91	113.4	0.76	0.80		
Milk N (lb.)					0.151	0.45
b	0.00212	— 0.000377	0.0277	0.15801		
t	1.47	4.54**	0.84	1.44		
Urine N (lb.)					0.293	0.52
b	0.00414	— 0.000026	0.2205	—0.025908		
t	1.41	0.15	3.30**	1.15		
Efficiency (%)					31.28	0.67
b	—0.4844	— 0.02867	40.379	2.08014		
t	1.85	1.92	6.79**	1.05		
SILAGE						
Mean (x)	17.14	130.2	0.55	0.93		
Milk N (lb.)					0.122	0.36
b	0.00156	— 0.00170	0.0487	0.033540		
t	1.95+	5.15**	2.21*	3.39**		
Urine N (lb.)					0.228	0.32
b	—0.00430	0.000184	0.4001	0.002041		
t	1.86+	1.96+	6.34**	0.07		
Efficiency (%)					26.58	0.24
b	0.9476	— 0.01659	— 7.279	5.67443		
t	4.23**	1.81+	1.19	2.06*		

[1] **Significant at .01; *Significant at .05; +Significant at .10.
[2] Proportion of total variation due to variable.

relative requirements, then these data, Figure 6 and Table 17, suggest that nitrogen requirements for dairy cows are quite uniform throughout the lactation and are dependent on the cow's ability to consume digestible dry matter, as well as being contingent on milk production to the extent indicated in Morrison's feeding standards (**48**).

APPLICATION OF RESULTS

Digestible dry matter intake is the most important single factor determining the quantity of nitrogen utilized by dairy cows fed roughages on a free choice basis. It was calculated that, at the peak of lactation, an increased intake of 1 pound of digestible dry matter from soilage or hay daily may increase the milk production of Holstein cows (milk containing 3.06 percent protein) by 6.5 pounds daily and of Jersey cows (milk containing 3.92 percent protein) by 5 pounds daily. With forage crop silage the productive nitrogen response per unit dry matter is less. It would be 4 pounds of milk daily for Holsteins and 3 pounds of milk daily for Jerseys. In late lactation the amount of productive nitrogen per unit of digested dry matter intake declines.

As shown by the data discussed previously, the nitrogen-utilization-response from forages fed as freshly-cut forage is vastly different from that obtained with ensiled forages. Thus, at high levels of digestible dry matter intake, the nitrogen in soilage is used more efficiently per unit of dry matter intake, whereas, at suboptimal levels of dry matter intake, forage crop silage is used more efficiently per unit of dry matter intake. This difference, reflected in the regression lines for the two types of forage presented in Figure 6, helps answer the practical question, "Is it necessary to feed hay with forage crop silage?" If the forage is such that low levels of digestible dry matter intake are consumed the cows would decrease in milk production and quickly adjust to a lower level of productive nitrogen. The silage dry matter would be used more efficiently in producing milk nitrogen but the feed intake of forage fed as soilage or hay would be higher. As a result these two effects balance out and the resulting milk yields would be about the same with both types of roughage. The proportion of hay to silage experiment, recently carried out by Pratt, (**55**) is a case in point.

However, at higher levels of digestible dry matter intake, in which case the efficiency of nitrogen utilization of soilage and hay exceeds efficiency of silage, the nutrient needs of high producing cows are likely limited in all silage feeding programs. For example when one considers the production range of 50 to 60 pounds of milk per 1,000 pounds of body weight, the silage digestible dry matter required to convert the absorbed nitrogen to an equivalent amount of productive nitrogen in milk exceeds the amount most cows are able to consume. In contrast, this level of productive nitrogen in the form of milk may be attained with optimum intake of soilage because of a greater response in productive nitrogen per unit of digestible dry matter ingested.

Silage nitrogen is used most efficiently below 16 percent crude protein in the total ration and declines at higher levels of protein. Thus for efficient utilization of legume-grass silage nitrogen, rations should be balanced between 12 and 16 percent crude protein when the forage is principally silage. Because the nitrogen of legume-grass silages is used less efficiently than nitrogen from most other forages, it appears that the minimum digestible protein should be 8 percent of the total ration rather than the 6.5–7.0 percent, suggested for other types of roughages by the National Research Council, to meet the requirements of lactating dairy cows (**31**). On the other hand, when soilage is fed, efficient use of the nitrogen is made at extremely high levels of protein; that is, up to 23 percent, even though these rations may be considered unbalanced based on present criteria of balancing rations. Thus, young cut forage fed as soilage or hay is the most useful source of nitrogen in the dairy rations, studied to date, in that it is efficiently used and at the same time allows the cow to consume the maximum amounts of digestible dry matter.

Grain feeding tends to have an all or nothing effect. A small amount of grain increases efficiency of nitrogen utilization markedly but further additions had little effect. The addition of grain improves the digestibility of legume-grass silage nitrogen, presumably by increasing the growth of rumen microorganisms. For practical purposes 10 to 25 percent of the total ration dry matter in the form of grain will produce the maximum increase in efficienciy of nitrogen utilization that can be attained by adding grain. Grain feeding failed to improve the nitrogen efficiency in cows fed soilage.

SUMMARY

A series of eleven nitrogen balance experiments were carried out during a six-year period for the purpose of studying the effect of source of nitrogen on efficiency of nitrogen utilization. Separate collections of urine and feces were made in conjunction with digestion trials with lactating dairy cows. The effects on nitrogen efficiency and the digested dry matter intake of varying amounts of soybean oil meal, varying nitrogen content of the roughages fed, corn and legume-grass silages, field-chopped forage cut daily (soilage) through the season versus ensiled forage cut on two dates during the season and either of the last two with grain feeding versus no grain were studied.

When the nitrogen content of the ration was increased by substituting soybean oil meal for corn meal in the rations of cows fed legume-grass silage, the efficiency (sum of retained nitrogen and milk nitrogen ÷ nitrogen intake) of nitrogen utilization declineed at the rate of 1.9 percentage units per pound of soybean meal added. When legume-grass silage constituted the sole or major part of the roughage fed, the efficiency of nitrogen decreased rapidly (1.2 percentage units per pound of increase in protein equivalent intake) in rations where the protein equivalent of the total ration exceeded 15 percent. On the other hand, the nitrogen of soilage was utilized more efficiently for both body retention and milk nitrogen and the efficiency of nitrogen utilization remained essentially constant as the level of protein in the total ration increased to as high as 23 percent. The efficiency rose by 6.5 percentage units per pound of increase in protein equivalent consumed.

The efficiency of nitrogen utilization was higher when corn silage and alfalfa hay or corn preserved legume-grass silage was fed than when legume-grass silage was fed alone.

Grain feeding increased the efficiency of nitrogen utilization and apparent protein digestibility of cows fed ensiled legume-grass silage but did not increase the efficiency significantly when fed with soilage.

Efficiency of nitrogen utilization increased significantly with increased digested dry matter intake per 1000 pounds of body weight.

The response, in amount of nitrogen used for tissue and milk, to increased digested dry matter intake per 1000 pounds of body weight was greater for soilage than for the ensiled forage.

Procedures used for separate collection of feces and urine in the stanchion stalls regularly used by the cows are described.

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APPENDIX TABLE 1.—Dry Matter and Nitrogen Composition of Feeds

Feed and Experiment	Dry Matter	Total Nitrogen	Non Protein Nitrogen*	Protein Equivalent
	(%)	(%)	(%)	(%)
Experiment 1				
Legume-grass silage†	23.8	2.40	.84	14.9
Grain, 9% protein	88.0	1.57	----	9.8
Grain, 16% protein	88.0	2.54	----	15.9
Grain, 33% protein	88.0	5.31	----	33.2
Experiment 2				
Legume-grass silage	21.0	2.67	.95	17.2
Grain ration 1	80.0	2.36	----	14.8
Grain ration 2	80.0	2.00	----	12.5
Grain ration 3	82.3	1.85	----	11.6
Experiment 3				
Legume-grass silage‡	30.1	2.06	.90	12.9
SO_2 silage†	28.4	2.01	.88	12.6
Clover hay	91.0	1.72	----	10.2
Grain, #60	89.5	2.28	----	12.8
Grain	87.5	3.72	----	23.3
Experiment 4				
Silage, 1957	24.2	2.93	.76	18.3
Silage, 1958	28.0	2.64	.94	16.5
Soilage, 1957	16.9	3.22	.48	20.1
Soilage, 1958	15.9	3.21	.48	20.1
Grain	87.4	1.42	----	8.9
Experiment 5				
Silage	27.8	2.91	1.14	18.2
Alfalfa hay	87.0	2.85	.51	17.8
Grain	83.3	2.30	----	14.4
Experiment 6				
Silage, 1954	21.7	1.76	.63	11.0
Hay, 1954	88.4	1.86	.28	11.6
Silage, 1955	22.7	2.13	.76	13.3
Hay, 1955	88.3	2.22	.33	13.9
Silage, 1956	39.5	2.48	.88	15.5
Hay, 1956	89.0	2.35	.35	14.7
Grain	85.0	2.17	----	13.6
Experiment 7				
Alfalfa pellets	85.5	3.40	.61	21.3
Clover hay	89.0	2.36	.35	14.7
Grain	85.5	2.30	----	14.4

Feed and Experiment	Dry Matter	Total Nitrogen	Non Protein Nitrogen*	Protein Equivalent
	(%)	(%)	(%)	(%)
Experiment 8				
Corn silage	28.0	1.32	.30	8.3
Legume silage‡	30.2	2.58	1.05	16.1
Hay	92.0	1.40	.25	8.8
Grain	85.8	2.20	----	13.8
Experiment 9				
Corn silage	27.7	1.48	.34	9.3
Legume silage	34.3	2.10	.85	13.1
Hay	87.8	1.96	.29	12.3
Grain	87.0	2 60	----	16.3
Experiment 10				
Legume-grass silage	27.8	2.91	1.14	16.6
Legume-grass silage‡	28.0	2.71	1.10	16.9
Corn silage	29.5	1.15	.26	7.2
Grain	85.0	2.14	----	13.4
Soybean oil meal	92.0	6.66	----	41.6
Experiment 11				
Legume-grass silage	24.5	2.12	.83	13.3
Legume-grass silage‡	29.0	1.59	.64	9.9
Grain	86.5	2.07	----	16.9
Ear corn	79.3	1.49	----	12.9

*TCA soluble nitrogen.

†Preserved with 8 lb. of sulfur dioxide gas per ton of green material.

‡Preserved with 150 to 200 lb. of corn and cob meal per ton of green material.

APPENDIX TABLE II. Nitrogen Balances

Cow No.	Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
		Intake	Feces	Urine	Milk			
	(%)					(g./d.)		
1114–1	16.4	.48	.16	.27	.11	— 26.1	1	Legume-grass silage
1108–1	16.4	.49	15	.21	.09	5.1	1	Legume-grass silage
1108–2	16.4	.54	.21	.21	.11	19.1	1	Legume-grass silage
1076–1	16.4	49	.17	.19	.08	— 6 0	1	Legume-grass silage
843–1	16.4	.68	.25	.24	.16	9.9	1	Legume-grass silage
1014–1	16.4	.61	.22	28	.12	— 5.3	1	Legume-grass silage
1009–1	16.4	.55	.21	.26	.06	9.0	1	Legume-grass silage
1114–2	13.6	.38	.16	.13	.10	5.7	1	Legume-grass silage
1014–2	13.6	.43	.16	.15	.11	3.9	1	Legume-grass silage
843–2	22.7	.87	.18	.55	.12	8.1	1	Legume-grass silage
1009–2	22.7	.57	.14	.36	.05	8.1	1	Legume-grass silage
1106–1	15.9	.62	.19	.25	.20	— 9.1	2	Legume-grass silage
1161–1	15.9	.47	.17	.24	.08	— 6.5	2	Legume-grass silage
1170–1	15.9	.41	.14	.19	.10	— 16.2	2	Legume-grass silage
1172–1	15.9	.64	.23	.31	.12	— 9.1	2	Legume-grass silage
1170–2	15.9	.46	.13	.20	.12	+ 5.2	2	Legume-grass silage
1172–2	15.9	.71	.21	.28	.13	+ 38.0	2	Legume-grass silage
1170–3	15.9	.44	.13	.19	.12	+ 1.0	2	Legume-grass silage
1172–3	15.9	69	.19	.30	.13	+ 32.6	2	Legume-grass silage
1106–2	15.6	.61	.22	.22	.19	— 13.6	2	Legume-grass silage
1161–2	15.6	.46	.17	.20	.09	+ 1.5	2	Legume-grass silage
1106–3	15.3	.58	.19	.20	.19	— 2.2	2	Legume-grass silage
1161–3	15.3	44	.14	.20	.08	+ 10.0	2	Legume-grass silage
910–1	13.5	.46	.18	.13	.13	— 8.5	3	Silage + Hay
914–1	13.0	36	.14	.14	.09	— 12.8	3	Silage + Hay
910–2	13.2	19	10	07	.05	— 26.1	3	Hay + corn-preserved silage

APPENDIX TABLE II. Nitrogen Balances—Continued

Cow No.	Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
		Intake	Feces	Urine	Milk			
	(%)					(g./d.)		
914–2	12.3	.13	06	.05	.03	— 28.1	3	Hay + SO_2 silage
910–3	11.5	.22	.09	.07	.06	+ 28.3	3	Corn-preserved silage
914–3	12.0	24	.08	.08	.06	+ 10.7	3	SO_2 silage
910–4	12.0	.37	.15	.14	.09	— 11.3	3	SO_2 silage
914–4	11.5	.41	.17	.11	.10	+ 11.4	3	Corn-preserved silage
910–5	12.9	53	.16	.18	.11	+ 20.4	3	SO_2 silage
914–5	12.9	.60	.16	.22	.11	21.9	3	SO_2 silage
1208–1	17.4	.44	.16	.18	.11	— 3.9	4	Silage
1208–2	18.7	43	.16	.26	.09	— 30.4	4	Silage
1204–1	17.6	.55	.18	.20	.10	25.9	4	Silage
1204–2	15.4	.49	.17	.21	.11	6.3	4	Silage
1242–1	15.8	.55	.21	.16	.12	9.7	4	Silage
1242–2	15.6	.46	.17	.16	.12	29.9	4	Silage
1215–1	24.6	.71	.15	.16	.12	47.8	4	Soilage
1215–2	23.1	.88	.19	.17	.12	185.0	4	Soilage
1227–1	21.3	.85	.19	.33	.17	73.8	4	Soilage
1227–2	20.7	.86	.22	.37	.16	97.6	4	Soilage
1232–1	19.8	.86	.23	.29	.16	88.2	4	Soilage
1232–2	19.6	.87	.24	.29	.15	86.2	4	Soilage
1260–1	17.1	.41	.18	.18	.10	— 20.0	4	Silage
1260–2	15.3	.49	.20	.20	.09	0.9	4	Silage
1260–3	16.5	.55	.19	.21	.09	27.2	4	Silage
1260–4	14.3	.38	.15	.13	.07	11.8	4	Silage
1260–5	18.3	.41	.11	.22	.06	6.3	4	Silage
1232–1	15.4	.69	.30	.27	.16	— 13.6	4	S'lage
1232–2	15.0	82	.30	25	.15	52.6	4	Silage

APPENDIX TABLE II. Nitrogen Balances—Continued

Cow No.		Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
			Intake	Feces	Urine	Milk			
		(%)					(g./d.)		
1232–3		15.7	.77	.24	.27	.16	43.6	4	Silage
1232–4		13.8	.53	.19	.16	.11	40.0	4	Silage
1232–5		17.5	62	.20	.32	.11	3.6	4	Silage
1259–1		15.4	.66	.27	.23	.15	— 25.4	4	Silage
1259–2		14.4	67	.19	.21	.14	13.6	4	Silage
1259–3		15.1	.65	.19	.20	.16	46.2	4	Silage
1259–4		13.5	47	.17	.13	.10	29.1	4	Silage
1259–5		17.6	.56	.15	.27	.10	19.0	4	Silage
1277–1		19.3	.75	.20	.33	.16	29.1	4	Soilage
1277–2		15.2	.57	.19	.28	.13	— 15.4	4	Soilage
1277–3		21.2	.87	.23	.32	.16	68.0	4	Soilage
1277–4		22.2	.89	.21	.43	.12	59.9	4	Soilage
1277–5		21.1	.81	.19	.36	.12	66.2	4	Soilage
1134–1		17.4	.88	.22	.33	.22	52.4	4	Soilage
1134–2		13.7	.68	.26	.27	.19	0.0	4	Soilage
1134–3		19.4	1.06	.28	.38	.22	82.6	4	Soilage
1134–4		20.0	1.09	.27	.44	.19	84.4	4	Soilage
1134–5		19.1	.97	.23	.33	.16	113.5	4	Soilage
1227–1		16.6	.81	.22	.29	.18	54.5	4	Soilage
1227–2		13.5	.56	.23	.20	.15	— 6.3	4	Soilage
1227–3		19.0	.86	.22	.34	.16	62.6	4	Soilage
1227–4		19.5	90	.24	.35	.14	76.2	4	Soilage
1227–5		18.8	83	.20	.30	.13	90.8	4	Soilage
1347	(3:1)	16.3	56	16	.23	.09	39.9	5	Silage
1347	(3:1)	17.5	61	.20	.26	.11	12.5	5	Silage
1214	(3:1)	17.4	79	28	.34	.12	22.8	5	Silage

APPENDIX TABLE II. Nitrogen Balances—Continued

Cow No.		Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
			Intake	Feces	Urine	Milk			
		(%)					(g./d.)		
1345	(2:1)	16.3	.60	.17	.27	.11	21.0	5	Silage
1346	(2:1)	16.2	.58	.16	.26	.10	29.6	5	Silage
1235	(2:1)	17.3	.79	.28	.36	.18	— 9.1	5	Silage
1346	(2:1)	17.2	.65	.20	.31	.12	9.1	5	Silage
1264	(3:1)	18.4	1.00	.25	.33	.13	129.4	5	Alfalfa hay
1347	(3:1)	18.6	.77	.22	.29	.09	79.8	5	Alfalfa hay
1264	(3:1)	12.9	1.01	.29	.34	.17	93.0	5	Alfalfa hay
1347	(3:1)	12.9	.61	.24	.32	.10	— 19.3	5	Alfalfa hay
1235	(2:1)	16.2	.91	.25	.31	.15	93.5	5	Alfalfa hay
1346	(2:1)	17.6	.86	.22	.29	.09	79.8	5	Alfalfa hay
1235	(2:1)	12.9	.67	.30	.29	.17	— 37.5	5	Alfalfa hay
1346	(2:1)	12.9	.71	24	.32	.08	30.6	5	Alfalfa hay
1014		11.1	.48	.17	.15	.15	0.0	6	Silage
1108		11.1	.47	.16	.16	.12	12.1	6	Silage
1159		11.1	.39	.14	.14	.10	7.9	6	Silage
895		11.1	.53	.18	.21	.12	11.1	6	Silage + 20% hay
1112		11.1	.45	17	.16	.12	2.3	6	Silage + 20% hay
1129		11.1	.42	.15	.15	.09	17.9	6	Silage + 20% hay
843		11.1	.60	.21	.23	.13	17.0	6	Silage + 50% hay
1170		11.1	38	.15	.14	.09	— 2.2	6	Silage + 50% hay
1105		11.1	.55	.20	.21	.15	— 5.8	6	Silage + 50% hay
843–2		13.6	.66	.19	.29	.15	16.8	6	Silage + 50% hay
843–1		13.6	.58	.19	.27	.16	— 18.8	6	Silage + 50% hay
1112–2		13.6	.51	.18	.25	.13	13.6	6	Silage + 50% hay
1112–1		13.6	.53	16	.22	.15	— 4.4	6	Silage + 50% hay
1137–1		13.7	.59	19	.27	.14	— 3.2	6	Hay + 20% silage

APPENDIX TABLE II. Nitrogen Balances—Continued

Cow No.	Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
		Intake	Feces	Urine	Milk			
	(%)					(g./d.)		
1137–2	13.7	.62	.19	.22	.15	6.0	6	Hay + 20% silage
1073–2	13.7	.61	.18	.26	.15	+ 14.4	6	Hay + 20% silage
1073–1	13.7	.51	.15	.23	.16	— 9.1	6	Hay + 20% silage
1159–2	13.7	49	19	26	.11	— 20.1	6	Hay
1159–1	13.7	.54	21	.20	15	— 9.1	6	Hay
1108–1	13.7	59	22	.26	.20	— 57.1	6	Hay
1108–2	13.7	.65	.19	.28	.17	4.6	6	Hay
1184–1	14.8	.64	.28	.16	.14	27.2	6	Silage
1184–2	14.8	.48	.20	.16	.10	0.0	6	Silage
1132–1	14.5	.67	.23	.20	.17	39.7	6	Silage + 50% hay
1132–2	14.5	81	.32	.23	.14	57.8	6	Silage + 50% hay
1159–1	14.2	.63	.19	.22	.15	34.1	6	Hay
1159–2	14.2	.56	.17	.25	.12	13.6	6	Hay
1227	19.2	.76	.25	.35	.10	25.9	7	Alfalfa pellets
1137	19.8	.99	.34	.37	.18	46.0	7	Alfalfa pellets
960	19.2	1.10	.39	.35	.17	74.5	7	Alfalfa pellets
1215	19.1	.89	.32	.34	.14	42.8	7	Alfalfa pellets
1129	20.1	89	.29	.36	.11	57.1	7	Alfalfa pellets
1134	19.3	1.00	.38	.39	.19	15.9	7	Alfalfa pellets
960–1	9.7	40	.18	.18	.12	— 35.2	8	Corn silage + hay
1134–1	9.7	.36	.17	.18	.10	— 42.0	8	Corn silage + hay
1137–1	9.7	.39	.16	.15	.11	— 11.2	8	Corn silage + hay
1214–1	9.7	38	.15	.11	.11	5.6	8	Corn silage + hay
960–2	15.5	71	.22	.31	.12	16.1	8	Corn-preserved silage
1134–2	15.5	.69	.22	.31	.10	17.9	8	Corn-preserved silage
1137–2	15.5	65	.22	.27	.11	17.6	8	Corn-preserved silage

APPENDIX TABLE II. Nitrogen Balances—Continued

Cow No.	Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
		Intake	Feces	Urine	Milk			
	(%)					(g./d.)		
1214–2	15.5	55	.16	.25	.10	16 5	8	Corn-preserved silage
960–3	15.5	78	.25	.32	.11	17.5	8	Corn-preserved silage
1134–3	15.5	.71	.25	.36	.12	31 8	8	Corn-preserved silage
1137–3	15 5	.68	23	.27	.12	— 45.4	8	Corn preserved silage
1214–3	15 5	.56	.20	.22	.10	41.9	8	Corn-preserved silage
960–4	15 5	.71	.25	.26	.10	30 6	8	Corn-preserved silage
1134–4	15.5	.68	.23	.28	.12	35.2	8	Corn-preserved silage
1137–4	15.5	.63	.21	.23	.12	23.8	8	Corn-preserved silage
1214–4	15.5	.56	.19	.20	.11	44.3	8	Corn-preserved silage
1231–1	12.9	44	.14	.12	.16	6 8	9	Corn silage + hay
1193–1	12.9	51	.18	.20	.13	1.9	9	Corn silage + hay
1342–1	12.9	.49	.17	.16	.13	18 7	9	Corn silage + hay
1343–1	12.9	44	.14	.12	.17	7.5	9	Corn silage + hay
1231–2	12.9	.49	.14	.15	.14	26 1	9	Corn silage + hay
1193–2	12.9	58	.16	.16	.10	72 0	9	Corn silage + hay
1342–2	12.9	.50	.16	.12	.12	26.5	9	Corn silage + hay
1343–2	12.9	51	18	.13	.14	41 9	9	Corn silage + hay
1231–3	12.9	42	15	.13	.14	1.7	9	Corn silage + hay
1193–3	12.9	.53	.20	.21	.12	— 1.0	9	Corn silage + hay
1342–3	12 9	45	17	.14	14	3 8	9	Corn silage + hay
1343–3	12 9	47	.17	.13	.17	— 4 4	9	Corn silage + hay
1231–4	14.5	50	.14	.17	.12	30 9	9	Legume silage + hay
1193–4	14 5	.63	.17	.23	.10	46.7	9	Legume silage + hay
1342–4	14 5	54	.14	19	.12	36 1	9	Legume silage + hay
1343–4	14.5	54	18	.20	.14	7.8	9	Legume silage + hay
1231–5	14.5	48	14	.20	.13	8.1	9	Legume silage + hay

APPENDIX TABLE II. Nitrogen Balances—Concluded

Cow No.	Protein in Ration	Nitrogen, lb./d.				Nitrogen Balance	Expt.	Roughage Fed
		Intake	Feces	Urine	Milk			
	(%)					(g./d.)		
1193–5	14.5	.64	.18	.25	.11	45 8	9	Legume silage + hay
1342–5	14.5	.55	.16	.25	.11	14 5	9	Legume silage + hay
1343–5	14.5	58	.16	.22	.14	26 4	9	Legume silage + hay
1231–6	14.5	.48	.12	.19	.12	22.8	9	Legume silage + hay
1193–6	14 5	.61	.16	.25	.10	43 9	9	Legume silage + hay
1342–6	14.5	.57	.14	.23	.11	35 0	9	Legume silage + hay
1343–6	14.5	.58	.17	.21	.14	30.2	9	Legume silage + hay
1235–1	17.3	.57	.22	.19	.14	— 9.1	10	Legume-grass silage
1346–1	17.3	.52	.18	.14	.09	+ 9.1	10	Legume-grass silage
1345–1	15.1	50	.17	.21	.10	— 12 5	10	Corn and grass silage
1270–1	15.3	39	.15	.10	.10	— 13.9	10	Corn and grass silage
1235–2	14 3	.55	.19	.21	.14	1.1	10	Corn-preserved grass silage
1346–2	16 3	59	.16	.22	.09	51.1	10	Corn-preserved grass silage
1345–2	15 1	.47	.17	.19	.09	9.1	10	Corn preserved and corn silage
1270–2	14.9	.46	.16	.18	.10	9 1	10	Corn-preserved and corn silage
1235	9.9	.30	.14	.08	.12	— 15.4	11	Corn-preserved silage
1343	9.9	.35	.15	.10	.10	+ 1 9	11	Corn-preserved silage
1270	12.3	.39	.14	.14	.09	8 2	11	Silage
1347	12 2	.42	.15	.15	.10	19 1	11	Silage
1184	13 5	.52	.17	.18	.15	20.4	11	Silage
1258	13.5	.46	15	17	.10	25 0	11	Silage