NITROGEN METABOLISM IN DAIRY CATTLE. I. THE INFLUENCE OF GRAIN AND MEADOW CROPS HARVESTED AS HAY, SILAGE, OR SOILAGE ON EFFICIENCY OF NITROGEN UTILIZATION

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SUMMARY

Efficiency of nitrogen utilization was studied in four experiments involving varying proportions of silage and hay, comparisons of silage and freshly cut meadow crop (soilage), effects of grain feeding, and feeding different ratios of roughage to grain. Feces and urine were collected separately and nitrogen balance and milk nitrogen determined. In all trials, lactating cows were allowed to eat roughage ad lib. No differences in nitrogen efficiency or urine losses were observed in cows fed different proportions of hay and silage. The nitrogen utilization response from freshly cut forages was different from that obtained with ensiled forages. Below 15% protein equivalent in the total ration, silage and soilage nitrogen were used with the same efficiency. Silage nitrogen declined in efficiency at higher levels, whereas soilage nitrogen was used as efficiently at the highest levels of protein equivalent measured as at the lowest. Adding grain to forage rations increased the efficiency of nitrogen utilization markedly, but increases in the grain content which raised the amount of grain from a 3:1 ratio of roughage to grain to a 2:1 ratio were without further effects.

Efficiency of nitrogen utilization is of particular interest in dairy cattle feeding trials. Fundamentally, cost efficiency in feeding dairy cattle has been based on the utilization of forages as the principal sources of nitrogen and energy.

That many dairymen were feeding higher levels of protein equivalent than could be used efficiently by dairy cows seemed probable, because of the continued trend toward increased production of high-nitrogen, more digestible roughages. This study was done with the present emphasis on efficiency of farm production in mind, in an effort to define more clearly the nitrogen status of dairy cows under conditions of free choice roughage consumption.

Practical feeding experiments and nitrogen balance studies are the common methods used in evaluating the protein of feeds. Feeding experiments have had the practical advantage of measuring the end results in terms of a salable product (milk). The classical studies on protein requirements were made by this method (5, 8, 9). However, they required a relatively long period of time and provided no information on the metabolism of nitrogen.

In nitrogen balance experiments the nitrogen consumed in the feed is determined along with the output nitrogen in the urine, feces, and milk in the case of lactating cows. These figures provide a measure of nitrogen metabolism and may be used to compute apparent digestibility and the efficiency with which nitrogen is used for productive purposes (4).

Critical levels of nitrogen intake which will keep the test animal in approximate nitrogen balance must be used when comparing the protein value of different kinds of feeds, and the results apply only for the physiological state of the
experimental animal (1). 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 (3, 9, 12). 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 nitrogen efficiency.

In the following experiments the efficiency of nitrogen utilization and urine losses were studied in dairy cattle fed free choice different roughages varying in protein content. Other variables incorporated in this study were the amount of grain fed, proportion of silage to hay, and a comparison of freshly cut versus ensiled forage.

**EXPERIMENTAL PROCEDURES**

Apparent protein digestibility and nitrogen balance were determined in cows on various experimental regimes for collection periods of five or seven days. Dry matters were determined by oven drying, except for silage, which was determined by toluene distillation. The nitrogen content of the feed, feces, urine, and milk was determined, using the Kjeldahl procedure. In all cases fresh or refrigerated samples were used. Urine samples were preserved with hydrochloric acid or thymol.

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

The 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. The separate collection of urine and feces was facilitated by the use of rubber mats for cow beds; Sisalkraft paper strips, 4 by 5 ft., on which the feces were collected; and Gooch tubing urinals, similar to those described by Hansard (6), which were attached to small-mouthed metal milk pails. Urine collection pails were emptied twice daily. Electrical stall trainers were used to make the cows stand at the back of the stall for defeation.

**Experiment 1.** 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 hay and silage were harvested from alternate strips of the same fields. The nitrogen metabolism studies were carried out over a period of 3 yr. Grain was fed throughout the experiment in proportion to the amount of roughage consumed (3:1 ratio). The grain concentrate ration was composed of 450 lb. of corn, 300 lb. of oats, 100 lb. of wheat bran, 50 lb. of soybean oil meal, and 10 lb. of salt. The proportion of silage and hay fed, protein content of the roughages used, and the year in which the experiments were conducted are shown in Table 1.

The protein digestion and nitrogen balance trials were carried out with cows in their third and fourth months of lactation during the fourth, sixth, or eighth wk. of the 16-wk. feeding period.

**Experiment 2.** The nitrogen metabolism studies in this experiment were carried out to obtain further data on the effects of various levels of grain feeding when freshly cut (soilage) or ensiled meadow crops (silage) were fed.
Proportions of hay and silage and protein content of the roughages fed in Experiment 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Cows</th>
<th>Trials</th>
<th>Silage (%)</th>
<th>Hay (%)</th>
<th>Protein content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>11.1</td>
</tr>
<tr>
<td>1954</td>
<td>3</td>
<td>3</td>
<td>80</td>
<td>20</td>
<td>11.1</td>
</tr>
<tr>
<td>1954</td>
<td>3</td>
<td>3</td>
<td>50</td>
<td>50</td>
<td>11.1</td>
</tr>
<tr>
<td>1955</td>
<td>2</td>
<td>4</td>
<td>50</td>
<td>50</td>
<td>13.6</td>
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<td>1955</td>
<td>2</td>
<td>4</td>
<td>20</td>
<td>80</td>
<td>13.8</td>
</tr>
<tr>
<td>1955</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>100</td>
<td>13.9</td>
</tr>
<tr>
<td>1956</td>
<td>1</td>
<td>2</td>
<td>100</td>
<td>0</td>
<td>15.5</td>
</tr>
<tr>
<td>1956</td>
<td>1</td>
<td>2</td>
<td>50</td>
<td>50</td>
<td>15.1</td>
</tr>
<tr>
<td>1956</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>100</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Digestion and nitrogen balance trials were carried out with Jersey cows fed each of the following regimes: Ration 1—Silage with no grain; Ration 2—silage with one-half grain; Ration 3—silage with full grain; Ration 4—soilage with no grain; Ration 5—soilage with one-half grain; Ration 6—soilage with full grain. The cows in the one-half grain blocks were fed 0.25 lb. of grain daily per pound of milk over 12 lb. The cows in the full grain blocks were fed 0.5 lb. of grain daily per pound of milk over 12 lb.

Five-day digestion and nitrogen balance trials were used. In 1957, two trials with one cow on each ration were carried out, beginning on May 25 and June 2. In 1958, a series of five digestion and nitrogen balances was completed, using one cow on each ration and starting with May 26 and at 4-wk. intervals thereafter through the summer. The soilage (freshly cut meadow crop) 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% corn and cob meal, 33% ground whole oats, and 1% iodized salt.

Experiment 3. This experiment was done to study further effects of minimum amounts of grain on nitrogen efficiency in milking cows fed soilage and changes in nitrogen metabolism with increasing plant growth and maturity.

Two cows were fed grain and soilage, and soilage alone was used as the control ration for two other cows. Grain was fed at the daily rate of 1/4 lb. per pound of milk produced above 12 lb. daily. Three digestion trials were carried out on each regime during the summer feeding period. A mixture of equal parts of corn and cob meal and ground whole oats was used as the only grain concentrate.

Two pairs of cows fed soilage only were used on alternate weeks to determine the changes in apparent protein digestion and nitrogen utilization for a 5-wk. period starting May 23 and on the 42-day second- and 35-third-cutting aftermath growths.

Experiment 4. In this experiment the effects of feeding of two ratios (3:1 and 2:1) of roughage-to-grain on the efficiency of nitrogen utilization were
studied. Four cows which had been adjusted to legume-grass silage feeding over a 2-mo. period were divided into groups of two and fed either a 3:1 or 2:1 ratio of roughage to grain. After a 2-wk. preliminary period, the first 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 forage (dry basis) to grain. The only exception was that the quantity of silage and grain fed were held constant during the feces collection periods. Later, second-cutting alfalfa hay in early-bloom stage was used to replace all of the legume-grass silage in the ration, but the two ratios of hay to grain (3:1 and 2:1) were maintained. The digestion and nitrogen balance trials were conducted during the first and fifth week after alfalfa hay feeding was initiated.

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

RESULTS AND DISCUSSION

No notable differences in nitrogen efficiency or urine losses were observed in cows fed different proportions of hay and silage (Table 2). However, as will be noted later, differences would not be expected at the levels of protein used (11.6 to 14.8% total protein). The low apparent protein digestibility obtained in the third trial with the all-silage group was attributed to the high dry matter content of the silage (37 to 47%). Excessive heating caused some browning and apparently rendered the nitrogen less available.

<table>
<thead>
<tr>
<th>Silage hay ratio</th>
<th>Trials</th>
<th>Protein in ration (No.)</th>
<th>Protein digested (%)</th>
<th>Urine nitrogen (g/day)</th>
<th>Nitrogen balance (lb/day)</th>
<th>Milk production (lb)</th>
<th>Efficiency of nitrogen utilization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0</td>
<td>3</td>
<td>11.6</td>
<td>64.3</td>
<td>33.5</td>
<td>6.7</td>
<td>21.4</td>
<td>42.6</td>
</tr>
<tr>
<td>80:20</td>
<td>3</td>
<td>11.6</td>
<td>64.1</td>
<td>36.0</td>
<td>10.4</td>
<td>20.3</td>
<td>40.1</td>
</tr>
<tr>
<td>50:50</td>
<td>3</td>
<td>11.6</td>
<td>63.0</td>
<td>37.7</td>
<td>3.0</td>
<td>22.0</td>
<td>38.8</td>
</tr>
<tr>
<td>25:75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100:0</td>
<td>4</td>
<td>13.6</td>
<td>68.2</td>
<td>45.1</td>
<td>1.8</td>
<td>27.7</td>
<td>37.6</td>
</tr>
<tr>
<td>80:20</td>
<td>4</td>
<td>13.7</td>
<td>69.4</td>
<td>42.7</td>
<td>2.7</td>
<td>26.6</td>
<td>36.9</td>
</tr>
<tr>
<td>50:50</td>
<td>4</td>
<td>13.7</td>
<td>64.4</td>
<td>44.2</td>
<td>-20.5</td>
<td>31.6</td>
<td>42.6</td>
</tr>
<tr>
<td>0:100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100:0</td>
<td>2</td>
<td>14.8</td>
<td>56.4</td>
<td>30.2</td>
<td>22.1</td>
<td>21.6</td>
<td>37.4</td>
</tr>
<tr>
<td>80:20</td>
<td>2</td>
<td>14.5</td>
<td>63.8</td>
<td>28.0</td>
<td>48.7</td>
<td>32.5</td>
<td>33.6</td>
</tr>
<tr>
<td>50:50</td>
<td>2</td>
<td>14.2</td>
<td>69.9</td>
<td>39.5</td>
<td>23.8</td>
<td>21.9</td>
<td>31.5</td>
</tr>
<tr>
<td>0:100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

b Total nitrogen efficiency = \[\frac{\text{Intake N} - (\text{urine N} + \text{fecal N})}{\text{Intake N}}\] , Milk efficiency = \[\frac{\text{Milk N}}{\text{Absorbed N}}\]
Results of the silage vs. soilage experiments are summarized (Table 3). The data obtained in Experiment 3 using soilage only are presented also (Table 4). Nitrogen was used, in most cases, more efficiently when fed as soilage than as silage (Table 3). This is illustrated in a scattergram (Figure 1), in which total nitrogen efficiency obtained from individual nitrogen balances was plotted against the total protein equivalent of the ration. Forty-one trials in which silage was the only roughage fed are compared with 41 other trials in which soilage was fed. In no case were trials included in which the grain fed contributed more than 17% of the nitrogen. Thus, despite a variability in time of harvesting the two types of roughage, the 41 individual trials used are considered sufficient to be indicative of the general population of cows fed soilage and silage. As would be expected, the range in per cent of total protein in the soilage extended both lower and higher than was found in the ensiled forages, harvested at a time approximately optimum yield.

Silage nitrogen was used most efficiently when the content was below 15% total protein in the ration. Above this level efficiency dropped off sharply in the same way that efficiency has been shown to decline when the total protein content of the ration was raised by increasing the amount of protein concentrates (9). In contrast, nitrogen of legume-grass soilage was used at optimum efficiency at all protein levels measured up to 24.6%. This is of marked nutritional importance, since it is reflected both as additional yield in milk nitrogen and as retained nitrogen. The possibility exists that this difference in nitrogen utilization between

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**Fig. 1.** The efficiency of nitrogen utilization in dairy cows expressed as per cent of nitrogen intake utilized for milk production and nitrogen retention. The upper chart shows nitrogen efficiency for 41 individual trials when soilage (freshly cut meadow crop) was fed, and lower chart shows 41 individual trials in which silage (ensiled meadow crop) was fed.
TABLE 3
Efficiency of nitrogen utilization in dairy cows fed meadow crop silage or soilage with different levels of grain concentrate

<table>
<thead>
<tr>
<th>Roughage used</th>
<th>Amount of grain</th>
<th>Trials (No.)</th>
<th>Protein in ration (%)</th>
<th>Protein digested a</th>
<th>Urine nitrogen a</th>
<th>Nitrogen balance a</th>
<th>Milk production (lb/day)</th>
<th>Efficiency of nitrogen utilization a (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilage None</td>
<td>7</td>
<td>20.9</td>
<td>74.7</td>
<td>41.3</td>
<td>43.4</td>
<td>25.3</td>
<td>23.5</td>
<td>29.7</td>
</tr>
<tr>
<td>Soilage One-half b 7</td>
<td>18.8</td>
<td>73.5</td>
<td>36.1</td>
<td>72.1</td>
<td>38.5</td>
<td>28.7</td>
<td>27.3</td>
<td>35.9</td>
</tr>
<tr>
<td>Soilage Full b   7</td>
<td>18.1</td>
<td>72.0</td>
<td>36.2</td>
<td>64.6</td>
<td>28.7</td>
<td>27.3</td>
<td>35.9</td>
<td></td>
</tr>
<tr>
<td>Silage None</td>
<td>7</td>
<td>16.8</td>
<td>63.2</td>
<td>44.1</td>
<td>-1.2</td>
<td>19.1</td>
<td>31.9</td>
<td>18.1</td>
</tr>
<tr>
<td>Silage One-half b 7</td>
<td>15.7</td>
<td>64.6</td>
<td>37.8</td>
<td>22.6</td>
<td>25.7</td>
<td>31.0</td>
<td>27.3</td>
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<tr>
<td>Silage Full b</td>
<td>7</td>
<td>15.3</td>
<td>63.9</td>
<td>33.9</td>
<td>17.5</td>
<td>23.2</td>
<td>33.3</td>
<td>29.7</td>
</tr>
</tbody>
</table>

* Difference between adjacent means required for statistical significance: protein digested, 5.4; urine nitrogen, 6.3; nitrogen balance, 30.7; efficiency of nitrogen utilization for milk, 9.3; and efficiency of utilization for total nitrogen, 7.2. Statistical Methods, p. 251 (14).

b Cows in groups receiving a full feed of grain were fed at the rate of 0.5 lb. of grain per pound of milk produced above 12 lb. One-half grain groups received grain at one-half the rate fed the full grain group.
**TABLE 4**

Efficiency of nitrogen utilization for various cutting dates in dairy cows fed freshly cut meadow crop with different levels of grain concentrate

<table>
<thead>
<tr>
<th>Cutting date</th>
<th>Amount of grain (lb.)</th>
<th>Cows (No.)</th>
<th>Protein in ration (%)</th>
<th>Protein digested (%)</th>
<th>Urine nitrogen (g/day)</th>
<th>Nitrogen balance (lb/day)</th>
<th>Milk production (lb/day)</th>
<th>Efficiency of nitrogen utilization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 28</td>
<td>None</td>
<td>2</td>
<td>15.5</td>
<td>68.8</td>
<td>50.7</td>
<td>--22.6</td>
<td>28.2</td>
<td>38.6 (17.8)</td>
</tr>
<tr>
<td>June 4</td>
<td>None</td>
<td>2</td>
<td>13.9</td>
<td>65.2</td>
<td>48.0</td>
<td>--21.6</td>
<td>29.4</td>
<td>40.6 (17.3)</td>
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<td>June 11</td>
<td>None</td>
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<td>12.8</td>
<td>65.1</td>
<td>25.5</td>
<td>15.4</td>
<td>24.5</td>
<td>48.7 (39.9)</td>
</tr>
<tr>
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<td>None</td>
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<td>9.1</td>
<td>59.4</td>
<td>34.4</td>
<td>--12.7</td>
<td>21.6</td>
<td>60.1 (24.9)</td>
</tr>
<tr>
<td>June 25</td>
<td>None</td>
<td>2</td>
<td>7.8</td>
<td>57.6</td>
<td>30.5</td>
<td>--13.4</td>
<td>18.9</td>
<td>77.7 (27.1)</td>
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<td>July 30 b</td>
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<td>17.3</td>
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<td>77.0</td>
<td>22.4</td>
<td>21.0 (33.8)</td>
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<td>54.6</td>
<td>21.8</td>
<td>17.6 (27.2)</td>
</tr>
<tr>
<td>May 28</td>
<td>4.7</td>
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<td>15.0</td>
<td>68.5</td>
<td>42.3</td>
<td>--2.7</td>
<td>36.3</td>
<td>38.6 (26.3)</td>
</tr>
<tr>
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<td>2</td>
<td>8.5</td>
<td>63.4</td>
<td>23.4</td>
<td>8.9</td>
<td>27.0</td>
<td>55.8 (40.7)</td>
</tr>
<tr>
<td>July 30</td>
<td>3.0</td>
<td>2</td>
<td>16.2</td>
<td>76.1</td>
<td>49.0</td>
<td>72.7</td>
<td>29.7</td>
<td>24.1 (36.3)</td>
</tr>
</tbody>
</table>

* Indicates the middle date of collection period.
| Aftermath forage, alfalfa in one-half bloom stage, approximately 42-day growth.
| Aftermath forage, alfalfa in bud stage, approximately 35-day growth.

**TABLE 5**

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

<table>
<thead>
<tr>
<th>Roughage used</th>
<th>Hay:grain ratio</th>
<th>Trials (No.)</th>
<th>Protein in ration (%)</th>
<th>Protein digested (%)</th>
<th>Urine nitrogen (g/day)</th>
<th>Nitrogen balance (lb/day)</th>
<th>Milk production (lb/day)</th>
<th>Efficiency of nitrogen utilization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legume-grass silage</td>
<td>3:1</td>
<td>4</td>
<td>16.9</td>
<td>68.7</td>
<td>42.0</td>
<td>31.2</td>
<td>19.8</td>
<td>22.5 (21.5)</td>
</tr>
<tr>
<td>Legume-grass silage</td>
<td>2:1</td>
<td>4</td>
<td>16.8</td>
<td>69.9</td>
<td>46.0</td>
<td>16.7</td>
<td>23.9</td>
<td>27.4 (23.9)</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>3:1</td>
<td>4</td>
<td>15.7</td>
<td>69.7</td>
<td>39.2</td>
<td>21.9</td>
<td>20.9</td>
<td>20.9 (30.4)</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>2:1</td>
<td>4</td>
<td>15.4</td>
<td>66.9</td>
<td>38.4</td>
<td>20.0</td>
<td>25.5</td>
<td>25.5 (25.9)</td>
</tr>
</tbody>
</table>
A statistical study of the data was made to determine what effect each of various known variables had on nitrogen metabolism. The independent effects on milk nitrogen, urine nitrogen, and efficiency of stage of lactation, rate of feed intake (digestible dry matter per 1,000 lb. of body weight), total nitrogen intake, grain feeding (presence or absence), and type of forage used were assessed by computing a multiple regression on the silage and soilage data separately. The means and regression coefficients are shown (Table 6). It will be noted that, independent of the grain effect, the variations in dry matter consumed by cows
fed soilage had no significant effect on nitrogen utilization, whereas the dry matter consumed by the silage-fed cows was related to marked differences in efficiency (P < .01) and yield of milk nitrogen (P < .05). An explanation of this difference is seen by referring to the means of the digestible dry matter intakes. Twenty-one pounds of digestible dry matter per 1,000 lb. of body weight were consumed on the average by the cows fed soilage compared to 17 lb. when silage was fed. It is apparent, as others have observed (7, 13), that the cows fed silage failed to consume optimum amounts of roughage. This, in turn, limited the amount of energy available to utilize nitrogen and in some cases caused the cows to draw from their body tissue to the extent of throwing them into negative balance (Table 3). The differences in the effect on nitrogen utilization of soilage and silage, however, were not limited to dry matter intake. A difference in grain response to the two types of forage was noted (Table 6). Grain is shown to enhance the efficiency of nitrogen utilization independent of, or over and above, its effect on adding to the dry matter consumed. In the soilage-fed cows this effect was marked and highly significant, whereas with the silage-fed cows the effect was slight, nonsignificant, and could not be separated from the contribution it made through increasing the dry matter intake. This suggests that grain feeding may have two separate effects on nitrogen utilization, depending on the type and quantity of roughage consumed. First, increased efficiency may result from grain adding to the energy increment by augmenting the dry matter consumption and, secondly, by enhancing nitrogen utilization if the cows are already consuming maximum quantities of roughage energy.

In confirmation of Figure 1, a highly significant decline in the efficiency of nitrogen utilization in silage-fed cows receiving increasing levels of nitrogen is shown (Table 6). Essentially no relationship existed between amount of nitrogen intake and efficiency in cows fed soilage. As the nitrogen intake increased, urine nitrogen in the group fed soilage increased twice the rate found for the silage-fed group. Apart from grain feeding, the multiple regression analyses (Table 6) showed that the variability in digestible dry matter intake was unrelated to efficiency within the group of soilage-fed cows. Maximum efficiency was obtained with grain feeding. In consideration of these two observations, and the general axiom that energy intake is positively related to nitrogen retention (11), the data from the animals in Experiment 2 were expanded, using the trials where simultaneous comparisons were made between soilage and silage. The total of productively used nitrogen, the amount retained plus milk nitrogen, was plotted against each cow's rate of energy intake in terms of digestible dry matter per 1,000 lb. of body weight (Figure 2). These data indicate that increased digestible dry matter intake also increased markedly the amount of nitrogen utilized daily by soilage-fed cows, even though the efficiency with which it was used remained relatively constant.

As shown in Figure 2, and pointed out in the foregoing discussions, the nitrogen-utilization-response from roughages fed as freshly cut forages is vastly different from that obtained with ensiled forages. Thus, at the highest level of
digestible dry matter intake, the nitrogen in soilage was used most efficiently per unit of dry matter intake, whereas at the medium and lowest levels of digestible dry matter intake silage nitrogen was used most efficiently. This difference in nitrogen response in relation to digestible dry matter intake, reflected in the regression lines presented in Figure 2, offers a plausible explanation for the marked difference found among experiment station workers in comparative response of cows to hay and silage dry matter for milk production. For example, Stone et al. (15) and Kirsh and Jantzon (10) have found that ensiling enhanced both efficiency of dry matter utilization and milk production. Secondly, Pratt and Conrad (13) found efficiency of dry matter utilization to be increased in silage-fed cows compared to hay-fed animals, but total dry matter intake was less, resulting in approximately the same milk production. Thirdly, Hillman et al. (7) showed that the efficiency of dry matter utilization was highest for the silage-fed cows, but milk production was reduced by silage feeding.

Fig. 2. The amount of nitrogen used by dairy cows at varying levels of dry matter intake with both silage and soilage when roughage consumption was voluntary.
Two points stand out in the practical application of these results. First, silage nitrogen was used most efficiently below 15% protein equivalent in the total ration and declined at higher levels of protein. Secondly, young cut forage fed as silage was the most useful source of nitrogen studied, in that it was more efficiently used at higher protein levels than silage and at the same time allowed the cows to consume more digestible dry matter than was possible during silage feeding.

REFERENCES