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NITROGEN UTILIZATION FROM FORAGE FEEDING SYSTEMS FOR DAIRY CATTLE

The Ohio State University

Ph.D. 1982

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NITROGEN UTILIZATION FROM FORAGE FEEDING SYSTEMS
FOR DAIRY CATTLE

DISSERTATION

Presented in Partial Fulfillment of the Requirement for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Arlyn Judson Heinrichs, B.S., M.S.

* * * * *

The Ohio State University
1982

Reading Committee:
H. R. Conrad
C. F. Parker
R. W. VanKeuren

Approved By

Harry R. Conrad
Adviser
Department of Dairy Science
"The friend who can be silent with us in a moment of despair or confusion,
who can stay with us in an hour of grief and bereavement,
who can tolerate not knowing, not curing, not healing,
and face with us the reality of our powerlessness,
that is the friend who cares."

Henri Nouwen

To my best friend, who has taught me many things about life and how to make it through the rough times of life.

The most outstanding verse that you have taught me, not by word, but by your thoughts and deeds, comes from Matthew 7.13-14:

"Enter by the narrow gate; for the gate is wide and the way is easy that leads to destruction, and those who enter by it are many. 14. For the gate is narrow and the way is hard that leads to life, and those who find it are few."

I truly believe that you have found life, understand its meaning, and have helped show it to me.

This book is dedicated to my brother, Mike, with great admiration, respect and love.
ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. H. Russell Conrad for his guidance and encouragement, making this research possible. I also wish to thank my reading committee members, Dr. Charles F. Parker and Dr. Robert W. VanKeuren, for their helpful comments and suggestions. Appreciation goes to Dr. Donald E. Pritchard for his advice and cooperation throughout my program and for serving on my committee.

My deepest gratitude is extended to Joe Harrison for his assistance, criticisms, and long standing, ineffable friendship.

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VITA


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Effect of high fat diets on milk and fat production in
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Protein production and dry matter intake of grazing dairy
cattle. J. Dairy Sci. 64(Suppl. 1):110 (Abstract).

Added dietary fat for milk and fat production in commercial


FIELDS OF STUDY

Major Field: Animal Nutrition
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CHAPTER 1

INTRODUCTION

The dairy industry in the U.S. has changed dramatically from the small herd general farming, family operation of yesterday, to today's specialized farming operations. Still, dairy cattle consume some 51% of their total feed as forages (1). This exemplifies the importance of forages in dairy farming and the value of producing superior quality, high protein forages.

When this country was first settled, virtually all of the land was covered with forests and rangelands. Many of these lands were first brought into production for crops and pastures and then gradually taken out of agricultural production for cities, towns, and industries. Fifty years ago there were over 4.1 ha of cropland per person in the U.S. This has since decreased to less than 2 ha per person with the opportunity of bringing new land into production very limited (2).

The ruminant livestock industries in the U.S. are highly dependent upon a reliable source of forage as their primary feed base. In each aspect of the livestock industry, dairy, beef and sheep, essentially all are land-based, forage
utilizing operations. Reid (3) has stated that increased forage quality, resulting in increased forage intake and digestibility, account for some 20% of the increases in milk production as seen in the past 25 years. Much of the rest of the increase comes from genetics, management and an increase in grain feeding.

Improvement of forage quality is a dynamic process which must be considered before, during and after harvesting. One of the factors which denotes forage quality is the nitrogenous portion of the forage. This can be altered and improved before and after harvesting. The intent of this research was to examine several methods of improving forage protein and quality. First, by altering the species composition of a grass-legume pasture system, the amount of legume and therefore protein in the pasture is increased. A second study was the addition of anhydrous ammonia to corn silage, thereby increasing the protein and overall quality of this high-energy roughage.

There are many factors that contribute to and affect the actual intake of a forage after harvest. Many of these factors as outlined in Figure 1 can be influenced by management. These factors include the availability and balance of nutrients in the forage, alternate sources of feeds, and the overall environment. The remaining factors, including the acceptability, availability of forage, rate of passage, animal requirements and rate of eating, are less influenced
by management and therefore need to be studied with regard to various types of feedstuffs.

Improving the quality of forages produced as well as maximizing the intake of these forages, are important management tools to be utilized by livestock owners. These tools will help maximize animal output by utilizing the greatest amount of low cost, high-quality forage in the diet.
Figure 1. Various factors affecting forage intake and eventual animal output. Adapted from Noller, C. H., Grass-Legume Silage in Forages, M. E. Heath, D. S. Metcalfe, R. F. Barnes, 1973, Iowa State University.
LIST OF REFERENCES


CHAPTER 2

ALTERING THE COMPOSITION OF GRASS-LEGUME PASTURES
WITH PRONAMIDE

Legumes are commonly grown with grasses in pasture mixtures to improve the overall forage quality for the grazing animals. Species components of pasture mixtures, however, are not always mutually beneficial. Cooper (2) showed that if one species component of a grass-legume mixture gained from an association, the other species usually lost. Under most management practices, combining a grass and a legume in the same sward will result in a high quality pasture for one of two years. The weaker of the two species under stress, usually the legume, will be dominated by the grass after several seasons, leaving a predominately grass sward. Management practices that maintain the mixed population of grass and legumes would help extend the quality forage production from a sward for one or more seasons.

Several herbicides have been demonstrated to be effective in reducing the amount of grass in alfalfa-grass swards (8) resulting in the extended life of the mixed sward. While herbicides are ordinarily used to remove one species completely, allowing other species that tolerate the herbicide to
proliferate due to less plant competition, sublethal doses of herbicides have been found to be effective in reducing, not eliminating one species, thus favoring the other species. Pronamide [3,5 dichloro(N-1,1 dimethyl-2-propynyl)-benzamide] is one of these herbicides that has been shown to be effective in the control of many grasses and weeds in legume swards (4,6,8). In the studies by Dawson (4) rates as high as 6.7 kg/ha were applied to alfalfa stands without damaging the legume; however, rates of 1 to 1.8 kg/ha are more commonly used to control grasses in legume stands (6,7).

Chemically controlling weeds in established stands of legumes has been reported to decrease the total herbage yield while increasing the total alfalfa yield. Removing weeds from a mixed sward allows the legumes to increase dry matter yield per plant. The growth characteristics of the ladino clover allow a rapid increase in growth by stolons when competing plant species are diminished. Triplett et al. (8) reported that the alfalfa component of a forage stand was increased by 100 percent for the first cutting and was significantly increased in subsequent second and third cuttings indicating that the individual alfalfa plants were increasing their dry matter production with the reduction of competing species. Though herbicides may reduce the total forage yield by reducing the undesirable component of a stand, they may represent a major way to increase the quality of the forage produced.
This research was conducted to evaluate the effectiveness of using herbicides as a management tool in controlling the growth of competing grasses in a ladino clover-orchardgrass pasture and to evaluate these pastures in a rotational grazing pasture system for dairy heifers and lactating dairy cows.
MATERIALS AND METHODS

This experiment was established at the Ohio Agricultural Research and Development Center (OARDC) near Wooster, Ohio. Soil type was a Canfield silt loam soil (fine loamy, mixed mesic aquic fragiudalf) typical of soils used for pastures in this area. Two pastures were established in mid-May of 1977 with 'Saranac' alfalfa (Medicago sativa L.) and 'Pennlate' orchardgrass (Dactylis glomerata L.). At seeding time 330 kg of 6-10-20 fertilizer were applied per hectare. In October of 1977 lime was applied to these fields at the rate of 9 tons per hectare.

The harsh winters of 1978 and 1979 killed the majority of the alfalfa in these plots. Therefore on 10 April 1979 the lots were overseeded with ladino clover at the rate of 2.2 kg/ha. In November of 1979 330 kg of 0-4.3-25 fertilizer were applied per hectare. Likewise in November of 1980, 0-0-50 and 0-20-0 fertilizers were applied at the rates of 112 and 187 kg/ha, respectively. After 1979 ladino clover and orchardgrass were the predominant forage species present in these pastures and common dandelion (Taraxacum officinale L.) was the major perennial broadleaf weed species present.
The pastures were each subdivided into three sections and samples taken from each of these six plots were analyzed separately, but combined by treatment (1, 2, or 3) for reporting since plots treated the same were not found to be statistically different.

Pronamide was applied to plot 2 on 28 November 1979 at the rate of .84 kg per hectare. Pronamide was again applied on 18 November 1980 to plots 1 and 2 at the rate of .84 kg per hectare. All pastures were sampled two times per month from April through September during 1979 through 1981. During 1980 and 1981 three complete cuttings were made of the plots on approximately May 20, July 10 and August 30. Each plot was sampled at four locations where wire cages had been placed over the herbage to eliminate any possible grazing by animals present in the fields. These samples were separated and characterized by botanical composition and dried to determine total dry matter production per acre. All plots were cut at 2.5 cm above soil level. All samples were oven dried at 55°C and ground for analysis. Nitrogen was determined by the Kjeldahl method (1). Acid detergent fiber (ADF), insoluble ash, and neutral detergent fiber (NDF) synonymous to cell wall constituents (CWC), were determined as described by Van Soest (9) and Van Soest and Wine (10).

During the entire 1981 grazing period, six Holstein dairy heifers grazed these plots in a 5-day rotational grazing system. Heifers were individually weighed upon entering and leaving each plot to determine rate of gain. No other
supplements or feeds were given during this period as adequate forage was available at all times. Free choice trace mineralized salt and water were available. Sixteen lactating dairy cows were also in a 4-day rotational grazing system for two 24-day periods, one in early summer and the other in late summer. These animals also received 8 kg per head per day of a 9.6% crude protein grain mix consisting of 91.7% ground ear corn (Zea mays L.) plus supplemental minerals. Results of this study were analyzed by a standard analysis of variance and specific comparisons were made using Duncan's multiple range test.
RESULTS

Botanical Components and Yields

The chemical analysis of the samples taken from the plots in 1979 (Table 1) shows that no statistically significant differences exist between the three plots in any measured parameters. This analysis represents the average of samples taken throughout the entire growing season.

The botanical composition for the 1980 growing season are shown in Table 2. Plot 2, treated with pronamide, had significantly more ladino clover and less orchardgrass than the untreated plots 1 and 3. There was also a significant 3.4% increase in the amount of weeds in plot 2 for the first harvest. These weeds were predominately members of the Compositae family (dandelions) upon which pronamide has little to no effect. Although statistically significant, an increase in weed content of this magnitude would have little practical importance.

Chemical composition of the 1980 forage samples are in Table 3. Plots 1 and 3 were similar for all three cuttings while plot 2 (treated) had more protein, and significantly less cell wall contents, and therefore, more cell soluble matter (CSM) in cut 1 and 2.
Table 1. Chemical analysis of plots before treatment, 1979.

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<th></th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
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<tr>
<td>DM %</td>
<td>21.20</td>
<td>21.37</td>
<td>26.54</td>
</tr>
<tr>
<td>CP %</td>
<td>16.12</td>
<td>14.44</td>
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</tr>
<tr>
<td>ADF %</td>
<td>34.92</td>
<td>34.35</td>
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</tr>
<tr>
<td>ADF-N %</td>
<td>.19</td>
<td>.19</td>
<td>.18</td>
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<tr>
<td>CWC %</td>
<td>60.78</td>
<td>58.99</td>
<td>62.58</td>
</tr>
<tr>
<td>CSM %</td>
<td>39.22</td>
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<tr>
<td>Insol. Ash %</td>
<td>.0239</td>
<td>.0212</td>
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Table 2. Botanical composition of plots, 1980.

<table>
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<tr>
<th>Plot</th>
<th>Ladino Clover</th>
<th>Orchardgrass</th>
<th>Weeds</th>
<th>Ladino Clover</th>
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<th>Weeds</th>
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*Means within columns followed by like letters are not significantly different at the 5% level of probability according to Duncan's multiple range test.
Table 3. Chemical analysis of plots, 1980.

| Plot | CP  | ADF | CWC | CSM | CP  | ADF | CWC | CSM | CP  | ADF | CWC | CSM |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1    | 18.60<sup>a</sup> | 33.62<sup>a</sup> | 53.73<sup>a</sup> | 46.27<sup>a</sup> | 15.76<sup>a</sup> | 43.31<sup>a</sup> | 58.97<sup>a</sup> | 41.03<sup>a</sup> | 21.90<sup>a</sup> | 36.81<sup>a</sup> | 55.36<sup>a</sup> | 44.64<sup>a</sup> |
| 2    | 20.10<sup>b</sup> | 33.53<sup>b</sup> | 54.85<sup>b</sup> | 54.19<sup>b</sup> | 16.72<sup>a</sup> | 47.65<sup>b</sup> | 49.76<sup>b</sup> | 50.30<sup>b</sup> | 22.28<sup>a</sup> | 39.25<sup>a</sup> | 55.21<sup>a</sup> | 44.79<sup>a</sup> |
| 3    | 17.60<sup>a</sup> | 33.43<sup>a</sup> | 52.71<sup>a</sup> | 47.29<sup>a</sup> | 15.93<sup>a</sup> | 39.46<sup>a</sup> | 56.26<sup>a</sup> | 43.74<sup>a</sup> | 18.75<sup>a</sup> | 38.87<sup>a</sup> | 57.06<sup>a</sup> | 42.90<sup>a</sup> |

*Means within columns followed by like letters are not significantly different at the 5% level of probability according to Duncan's multiple range test.
The botanical compositions for the 1981 growing season are shown in Table 4. Plots 1 and 2 (treated) have significantly more ladino clover and less orchardgrass than does the control plot 3 in all three cuttings. Plot 1, treated for the first time, has significantly more weeds than the other two plots.

Chemical composition of these samples appear in Table 5. In all three cuttings, the treated plots contain significantly less cell walls and more cell soluble matter than does the untreated plot. The protein content is also higher in plots 1 and 2 and the fiber content lower, in both the first and third cuttings.

The total dry matter production from these plots are shown in Figures 1 and 2. In both years, the treated plots (plot 2 in 1980 and plots 1 and 2 in 1981) produced less dry matter in the first cutting, similar dry matter as the untreated plots in second and third cuttings, and therefore, less overall dry matter for the entire season.

Animal Performance

The average weight gains of the heifers grazing these plots are shown in Table 6. Due to the large number of seasonal variation, all plots were statistically similar, though plot 3 tended to have higher weight gains throughout the season.
Table 4. Botanical composition of plots, 1981.

<table>
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<tr>
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<th>Orchardgrass</th>
<th>Weeds</th>
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<td>69.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.14&lt;sub&gt;ab&lt;/sub&gt;</td>
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<td>2</td>
<td>46.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>0.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>98.94&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>98.57&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>0.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
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</table>

*Means within columns followed by like letters are not significantly different at the 5% level of probability according to Duncan's multiple range test.
Table 5. Chemical analysis of plots, 1981.

<table>
<thead>
<tr>
<th>Plot</th>
<th>CP</th>
<th>ADF</th>
<th>CWC</th>
<th>CSM</th>
<th>CP</th>
<th>ADF</th>
<th>CWC</th>
<th>CSM</th>
<th>CP</th>
<th>ADF</th>
<th>CWC</th>
<th>CSM</th>
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</thead>
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<tr>
<td>1</td>
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<td>35.57&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>53.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.22&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>49.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.52&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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<td>2</td>
<td>16.33&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>37.89&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>50.46&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>53.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.18&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>12.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>57.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.93&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>62.39&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37.61&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Means within columns followed by like letters are not significantly different at the 5% level of probability according to Duncan's multiple range test.
Fig. 1. Dry matter yield of treated plot 2 and control plots 1 and 3.
Fig. 2. Dry matter yields of treated plots 1 and 2 and control plot 3.
Table 6. Heifer gains, 1981.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Gain/Heifer/Day</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.69</td>
<td>.37</td>
</tr>
<tr>
<td>2</td>
<td>0.44</td>
<td>.32</td>
</tr>
<tr>
<td>3</td>
<td>1.36</td>
<td>.23</td>
</tr>
</tbody>
</table>

Table 7. Milk production.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Total (kg)</th>
<th>FCM (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.4&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>2</td>
<td>18.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>19.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Means within columns followed by like letters are not significantly different at the 5% level of probability, Duncan's multiple range test.
The milk production obtained from lactating animals during the rotational grazing period is shown in Table 7. No differences in total milk production were observed; however, 4% fat corrected milk production was significantly greater on the control plot which had an increased herbage dry matter production, as well as containing more ADF than the other plots.
DISCUSSION

The results of the botanical composition of the pastures in the first two cuttings of 1980 show the expected reduced amount of orchardgrass and increase in ladino clover, similar to results obtained by Triplett et al. (9). In the third cutting in late summer, there were no differences in plots 1 and 2, indicating that the orchardgrass had recovered from the low level of herbicide application. The increase in amount of weeds observed in the first cutting was anticipated since a reduction of the dominant grass species, allowed an early increase in weed growth. Later cuttings did not have these differences in weeds as the orchardgrass and ladino clover filled in the open areas of the herbage canopy.

The botanical composition results obtained in 1981 are similar to those obtained in 1980. The plots contained a reduced amount of orchardgrass in the first two cuttings. However, in this third year after overseeding with ladino clover, the orchardgrass in the untreated plot 3 had completely dominated the plot and all but eliminated the ladino clover. The percent weeds was again higher in the plot treated for the first time. These were reduced in subsequent cuttings as the open spaces in the canopy filled in.
The total dry matter production per acre was reduced both years after pronamide application, most evident in the first cuttings. Due to the growth characteristics and total dry matter production potential per hectare of orchardgrass, any reduction in the percent of orchardgrass in a sward, even though it is replaced by ladino clover, would be expected to reduce overall dry matter production as observed. Reducing the dry matter production of these swards also reduces their animal carrying capacity and must be considered in an overall management system where pronamide is applied.

Pronamide has previously been reported to reduce first cutting yield in an alfalfa grass sward (8); however, subsequent harvests increased within yield in these studies, as expected with controlling grass in pure stands of alfalfa increases first cutting and total dry matter yields (6). Analysis of these samples for 1980 and 1981 shows an increase in crude protein content following pronamide application, reflecting the increased ratio of legume to grass. ADF content also follows this pattern being reduced in the treated plots.

Total digestibility and rate of degradation of cell soluble portions of forages is greater than the cell wall components. Another factor that reduces cell wall digestibility in high-producing ruminants is their increased rate of nutrient passage through the digestive tract. Regardless of the lignin content of a forage, the higher the ADF content, the less digestible the overall forage becomes to the high-producing animal. A notable difference in the treated plots
observed during both years was a significant decrease in NDF content, as reflected in less cell walls and more cell soluble matter. This indicates that the plots treated with pronamide were more digestible to these animals.

The weight gains of the heifers in this study have too large a degree of variation for differences to be significant. Body reserves of protein and energy could be reducing the analytical differences observed in these plots due to the short term rotation system used. An important point to clarify was that stocking rate was consistent in all plots even though total dry matter production was not equal. For this reason animal gut fill when leaving the untreated plots would be expected to be greater, thus affecting the weights. Another point was that the lower digestibility of the herbage in the untreated plots would decrease the rate of digestion and food passage, again influencing the weights of the animals leaving these plots.

The milk production showing no differences indicates no apparent problems with the acceptability of these forages. Animals going off feed would have influenced these values if one or more of the plots were less palatable. In a short term study such as this, where forages make up only about half of the total daily dry matter intake of the cows, and a grain mixture that is held constant throughout the time period makes up the other half of the intake, there would need to be great differences in these forages in order for there to be any observable difference in milk production. In all likelihood,
neither protein nor energy was lacking in any of these diets due to the high level of protein in all of the pastures and the high level of energy coming from the grain. The significant increase in 4% fat corrected milk on the untreated plot reflects the increased fiber content of this forage. An important point to note, however, with the untreated pastures is that they were consistently 15% or greater in protein content which is very adequate to support these levels of milk production in cows and growth in heifers.

At the rate of application used in this study, pronamide had little to no effect on dandelion or ladino clover, but reduced the orchardgrass component. The effect of increasing the weed component of the first cuttings was not determined in this study.

The animal evaluation from this study was not conclusive. However, differences could be expected if stocking rates were varied according to production and if the soils where these pastures were grown had been more depleted of nitrogen, so that the effect of the legume addition to the grass swards would create more dramatic differences.

From the dry matter production, botanical composition and analytical composition of these plots for three years, it can be concluded that low levels of pronamide application is beneficial to maintaining a mixed sward of orchardgrass and ladino clover. Applying pronamide for two consecutive years had no added beneficial effect in botanical composition over
the plots treated for one year. This study does show, however, that after three years without treating a mixed orchardgrass and ladino clover sward, the orchardgrass will dominate the sward and essentially eliminate the ladino clover. Therefore, to maintain the more highly digestible, mixed sward, and extend its productive life by manipulating its botanical composition, herbicide application is beneficial.
LIST OF REFERENCES


CHAPTER 3

FERMENTATION CHARACTERISTICS AND FEEDING VALUE
OF AMMONIA-TREATED CORN SILAGE

Non-protein nitrogen (NPN) has long been proven to be a useful addition to dairy diets and its benefit for lactating dairy cows has been extensively reviewed (7,14,16,25,28,29, 31,34).

Addition of NPN to corn silage diets has become a popular method of feeding these compounds (10,24). Increased use of complete mixed rations has augmented the use of NPN in corn silage diets allowing a more even distribution of NPN intake over the entire day and minimizing excess ammonia in the rumen and blood (19).

Ammonia addition to corn silage at the time of ensiling has become an economical source of NPN for dairy cows (14,21). Total nitrogen and lactic acid content of corn silage have been shown to increase in ammonia-treated silages, thus improving the overall feeding value of the forage (6,18).

Many studies where NPN treated corn silages were fed show equal or greater milk production over control groups fed natural protein (14,18,23,24,25,29). These studies also show a higher average persistency of milk production for NPN fed
cows. Cows fed ammonia-treated silage as the source of NPN had even greater persistency of milk production than those fed urea-treated silages. In experiments comparing ammonia-treated silages to urea-treated corn silages significant increases in milk production have been found with the ammonia-treated silage (18). Possible explanations for this are the increased lactic acid content of these silages and a higher dry matter digestibility found in ammonia- over urea-treated silages (24).

Many aspects of ammonia treatment to corn silage have not been investigated fully, especially in terms of fermentation patterns, feeding and intake responses and milk production responses.

The objectives of this study were to monitor the effects of added ammonia to corn silage in regard to anaerobic bacteria populations, fermentation patterns, animal feed intake behavior, and production responses when fed to lactating dairy cows.
MATERIALS AND METHODS

Late maturing corn (Zea mays L.) was harvested and alternate loads were stored in three tower silos (two 3.0 x 10.7 m. concrete stave and one 4.3 x 15.2 m. sealed). The silages stored in the concrete silos were treated with 3.2 or 4.5 kg of anhydrous ammonia per ton (35% DM basis) immediately prior to ensiling, while the third was untreated. Twelve weeks after filling, silos were opened and a feeding trial using 12 dairy cows in early lactation was carried out.

Silage samples were taken on alternate days and composited weekly to be used for chemical analysis. Dry matter determinations were done by toluene distillation. Methods as described by Huber et al. (18) were used to determine pH. Total nitrogen was determined by the Kjeldahl method, and tungstic acid precipitable nitrogen was determined by methods described by Winter et al. (36). VFA analyses were determined by gas chromatography. Fresh silage samples were taken one day per week to determine total anaerobic microbial numbers using methods described by Dehority (8) and Scott and Dehority (32). A mixture of corn silage and 360 ml of anaerobic dilution solution were mixed in a blender for 30 seconds. Roll tubes were inoculated with $10^{-6}$, $10^{-7}$ and $10^{-8}$ dilutions for
optimal counting range. Counts were determined one week after inoculation.

Animals used in this study, all in early lactation, were paired and assigned to one of four protein levels (12, 14, 16, 18% crude protein) according to pretrial milk production. All cows were assigned at random to one of the three silo groups at the start of the experiment. Each cow received each silage for a 20-day period in a split plot design, testing all silages within each protein level and adding an extra period to test for carry-over effects.

Milk production and feed intake were monitored daily. Milk protein was determined by the Kjeldahl method on samples taken on alternate days, with alternate A.M. and P.M. sampling. Milk fat was measured bi-weekly via infrared analysis.

All diets within protein group were made isonitrogenous using a combination of two grain mixtures, one containing 93.2% ground ear corn, the other 93.2% soybean meal plus minerals \(^1\). All diets were fed ad libitum at a 4 to 1 ratio (as fed) of corn silage to grain with a 5 to 10% refusal. Intakes were adjusted bi-weekly.

Feed intake patterns were determined with dairy heifers using methods described by Conrad et al. (5). Corn silage was the only feed given during these studies. Parameters used to define a meal were arbitrarily set at a minimum of 5 minutes

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\(^1\)Minerals were as follows: 2% limestone, 1% dicalcium phosphate, 1% iodized salt, 0.4% dynamate, 0.2% magnesium oxide, 0.2% selenium premix and 2% dried molasses.
eating, a minimum between meal interval of 6 minutes and a minimum meal size of .25 kg feed eaten.

Data were analyzed using a standard least squares analysis of variance program (12) and specific comparisons were made using Duncan's multiple range test.
RESULTS AND DISCUSSION

Silage Analysis

Silage analysis is shown in Table 1. On a dry matter basis the ammonia-treated silages increased in crude protein over the control silage by factors of 1.66 and 2.04. Total NPN content (tungstic acid N) was increased in the treated silages, however, not in relation to the amount of ammonia that was added. This is similar to results of Huber (19,21) which showed ammonia treatment inhibited plant protein breakdown. After fermentation, control silage contained 4.67% plant protein compared to 6.47 and 7.64% in the treated silages. Thus bound N constituted 76.6 and 90.4% of the total nitrogen in these forages. It has been reported previously that up to 90% of the total nitrogen of fresh herbage is in the form of true protein, while the remainder designated as the NPN fraction, consisting primarily of free amino acids, the amides glutamine and asparagine, and smaller amounts of amines, ureides and low molecular weight peptides (13). Our results suggest that a large portion of the original plant protein was preserved by the ammonia treatment. This corresponds with other reports of preserved protein in ammonia-treated silages (15,22).
Table 1. Analysis of silages

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>3.2 kg added/ton</th>
<th>4.5 kg added/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>38.09</td>
<td>36.81</td>
<td>36.75</td>
</tr>
<tr>
<td>Crude protein (DM basis)</td>
<td>8.45</td>
<td>14.05</td>
<td>17.22</td>
</tr>
<tr>
<td>Tungstic acid</td>
<td>44.69</td>
<td>53.93</td>
<td>55.67</td>
</tr>
<tr>
<td></td>
<td>Non-precipitable N (% of total N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>4.0</td>
<td>4.7</td>
<td>5.2</td>
</tr>
<tr>
<td>VFA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic</td>
<td>5.84</td>
<td>2.40</td>
<td>2.30</td>
</tr>
<tr>
<td>Propionic</td>
<td>0.47</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Butyric</td>
<td>0.60</td>
<td>3.49</td>
<td>5.76</td>
</tr>
<tr>
<td>Lactic</td>
<td>5.95</td>
<td>8.25</td>
<td>3.48</td>
</tr>
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</table>
Increased silage pH reflected the added ammonia concentration in the silage, showing the buffering effect of ammonia (20). Lactic acid concentration was increased in the low treated but decreased in the higher treated silages, consistent with previous reports (4,17,21). VFA analysis shows a marked decrease in acetic and propionic acid production of the treated silages. This also reflected part of the increased pH of these treated silages. Butyric acid was increased in treated silages. Butyric acid production in silages is indicative of hexose and lactate breakdown by clostridia organisms present on the plant material, normally indicating a poor fermentation in corn silage (36). There are a great variety of organisms including clostridia organisms present on fresh plant material (27). Ammonia additions to the plant material raise the pH significantly, the normal activities of the lactic acid bacteria cannot reduce the pH quickly enough and clostridial organisms are allowed to continue their growth in the silage (14).

Microbial Analysis

The analysis of the roll tubes for 10 weeks of sampling show total anaerobe counts of $11.4 \times 10^7$, $18.7 \times 10^7$ and $23.83 \times 10^7$ total colony forming units per gram of silage for the control, 3.2 kg and 4.5 kg added ammonia silages. Both ammonia-treated silages, although similar, are different ($P<.05$) from the control silage. This indicates that the higher
pH of the treated silage allowed the anaerobic bacteria to grow in greater overall numbers than the control silage. Alteration of VFA production also suggests that different species of bacteria proliferated in the treated silages and these continued to grow and multiply beyond those in the control silage where acetic, propionic and lactic acids lowered the pH more quickly.

Animal Production

Table 2 summarizes the production and dry matter intake of the cows on the trial. Actual percent crude protein in the total mixed rations during the course of the experiment averaged 11.7, 13.7, 15.6 and 17.6 percent crude protein. These differences were due to small variations in percent protein in the silages and grains and variations in feed intakes. Since the design of the experiment kept each cow within a certain level of protein while testing all three silos, the data are presented comparing silos only. No differences were found in periods 3 and 4, indicating no significant carry-over effects were present; therefore, the data presented represents only periods 1-3.

No differences in total milk production or dry matter intake were observed. There were significant increases in milk protein and fat percents in the 4.5 kg ammonia-treated silage as well as overall milk protein and fat production (kg/day).
Table 2. Milk yields and feed intakes of cows on corn silage diets.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>3.2 kg added/ton</th>
<th>4.5 kg added/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production (kg/day)</td>
<td>31.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>2.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.08&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk protein (kg/day)</td>
<td>0.92&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.94&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.29&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk fat (kg/day)</td>
<td>0.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.99&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dry matter intake (kg/day)</td>
<td>19.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup>Means on the same line with different superscripts are different (P<.05).
The increase in milk fat percent observed in both ammonia-treated silages is most likely due to the increased fiber in these rations since ground ear corn grain mixture replaced the soybean meal grain mixture. Milk fat percent increased with increasing ground ear corn in the ration and the differences were significant (P<.05) in the high ammonia-treated diets where the largest amount of ground ear corn was fed, and a more favorable rumen acetate to propionate ratio was achieved.

The decreased milk protein in the low level ammonia-treated silage group possibly reflects an inadequate balance of soluble and insoluble protein sources. Poorer utilization of NPN sources may be overcome in the higher ammonia-treated silage due to more plant protein preservation.

In studies by Foldager and Huber (10) and Huber et al. (17) increases were shown in milk protein production in cows receiving similar diets of ammonia-treated silage as the 3.2 kg ammonia added silage; however, their differences were not significant. In this experiment there was no difference between the control and 3.2 kg added ammonia silage, although both were somewhat lower than normal. When an increased amount of ammonia was added to the silage, we obtained higher levels of milk protein production. This response was most evident at the higher levels of dietary protein.

It has been reported that high-producing cows in the first third of lactation may respond to dietary protein
additions up to as high as 16 or 17% and possibly higher (11). Therefore, the increases in milk and milk protein production observed could be expected in the higher percent protein rations, or where a more favorable ratio of soluble to insoluble proteins existed.
Feed Intake Patterns

No significant differences were found in feed intake between the A.M. and P.M. feedings. Therefore, A.M. and P.M. data were combined for final analysis. The data for initial and subsequent meals are summarized in Table 3. While the number of meals were similar for all silages, there were fewer spontaneous meals on the high ammonia-treated corn silage rations. The weight of both initial and spontaneous meals were increased with the high ammonia-treated silage. Length of the meal was not significantly greater on these diets; however, by having larger meals, both the interval after the initial meal and all spontaneous meals were increased. Overall silage intake was not affected by ammonia treatment as reported previously (17).

An increase in the rate and amount of silage eaten at one meal suggests an increased acceptability and palatability of the silage. These data indicate that changes in the fermentation in the silage can result in changes in the eating patterns, palatability and acceptability of silages. Although many physiological functions change as a result of feeding, only a few appear to have an important influence in controlling meal size (29). Any combination of gustatory, olfactory or tactile stimuli can influence the amount of total feed intake and/or affect the feeding pattern of ruminants (1).

High levels of acetate, propionate, butyrate and a VFA mixture administered intraruminally have previously been found
Table 3. Number, weight and length of meals.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>3.2 kg added ammonia</th>
<th>4.5 kg added ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of meals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>17.3</td>
<td>20.0</td>
<td>11.3</td>
</tr>
<tr>
<td>Weight of meals (as fed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (kg)</td>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Spontaneous (kg)</td>
<td>1.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Length of meals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (min)</td>
<td>22.9</td>
<td>35.3</td>
<td>36.0</td>
</tr>
<tr>
<td>Spontaneous (min)</td>
<td>15.3</td>
<td>14.6</td>
<td>17.9</td>
</tr>
<tr>
<td>Interval between meals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (min)</td>
<td>29.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>60.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Spontaneous (min)</td>
<td>73.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>63.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>109.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total silage consumed (kg)</td>
<td>23.4</td>
<td>26.1</td>
<td>25.5</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means on the same line with different superscripts are different (P<.05).
to reduce dry matter consumption in dairy cattle (33). Therefore, the lower VFA levels along with higher pH may cause the increase in meal size of the ammonia-treated silages.

Many studies have reported a decrease in total dry matter intake where silage and fermented grains made up most of the diet of dairy cows (26,30).

It appears that the larger meal sizes observed result from increased pH of treated silage and due to less acetic, propionic and lactic acids present in these silages. Butyric acid present in the treated silages are apparently not enough to inhibit feed intake. The changes in the chemical make-up of the silage which occur during the fermentation process may be important factors in determining silage intake (5,35).

This study showed that ammonia treatment of corn silage resulted in a feedstuff of equal or greater value than corn silage with soybean meal supplement when fed to dairy cows in early lactation. Although feed intake patterns of animals consuming this forage were altered, overall intake of silage per day was not affected. The economic value of anhydrous ammonia over natural protein makes it a worthwhile protein source for dairy cattle.
LIST OF REFERENCES


CHAPTER 4

FEED INTAKE PATTERNS OF LACTATING DAIRY COWS

The investigation of feed intake behavior in animals is a complex and extensive field involving many diverse factors such as animal behavior, feed flavors, textures and odors, various feed components and additives as well as numerous anabolic and catabolic metabolites in the animal body (2,3,7). Physical and chemical properties of feeds may also affect overall feed intake (4). Factors regulating feed intake, both physical and physiological, change with digestibility of the diet. In diets of low digestibility, fiber capacity, rate of passage and dry matter digestibility were most important. Intake of highly digestible diets appeared to be proportional to metabolic size, animal production and dry matter digestibility. The measures become more precise if volume rather than weight is used to estimate fill (5).

Balch (4) has demonstrated that intake of silage was increased, proportional to the dry matter content of the silage. Studies showed in non-lactating animals, fibrous, bulky, dry feeds were eaten more slowly than moist pelleted feeds. There are many chemical factors, however, which may be involved in these responses to various roughages.
Baile and Forbes (3) showed that within normal physiological limits, pH of the ration would not likely limit intake. Factors such as propionate may have a great influence in controlling meal size and has been extensively studied (2). Insulin and insulin propionate interactions may also be involved in feed intake regulation. Bhattacharza and Alulu (6) found that insulin could increase uptake of propionate by the liver early in an eating period and thereby regulate feed intake. Plasma insulin increased in steers within 5 min. after eating under restricted intake conditions and longer (15 min.) when fed ad libitum (8).

It has been suggested that the initial meals are closely related to diet form and dry matter due to variations in the degree of mastication and deglutition that are required. This is also important in spontaneous meals, however, not to as great an extent as initial meals, which tend to be larger and longer in duration (13). Gustatory, olfactory or tactile stimuli can also influence the amount of total feed intake and feeding patterns in ruminants (1). Spontaneous meals, beyond the initial meal, are, however, probably most affected by rumen fermentation patterns and blood metabolites (13).

Little is known concerning the behavior of cows allowed to self-feed, and how their physical, climatic and social environments affect their eating behavior and level of intake. When competition for space at a feed trough or for feed are introduced into a feeding system, factors associated with
social dominance, aggression and persistency of individual cows may become important. Production patterns of cows are sometimes the most important factor in determining feed intake behavior (10); this may be dependent on the energy demands of the animal (5).

In all animals feed intake is a composite of meals; however, these are not always discreet and must be differentiated. Baile (2) has described three general criteria needed to define meals: minimum meal size, maximum time during which the minimum meal must be eaten, and the minimum between meal interval during which no food is eaten. He described all eating that occurred between meals as nibbling. Criteria used to describe a meal would be expected to vary between species of animals, various ages, and stages of production.

Much understanding is lacking on the factors which influence rates of eating and swallowing feeds. Such information is necessary to alter feeds and feeding systems that will allow for maximum feed intake for high-producing dairy cows.

The objective of this study was to determine the criteria necessary to accurately define a meal for a lactating dairy cow consuming a complete mixed ration. Initial meals in this system are quite well defined; however, differentiating between spontaneous meals and nibbling are not defined sufficiently to classify by size and time.
Another objective of this study was to determine what parameters and interactions are needed to develop a statistical model for evaluation of feed intake patterns in lactating dairy cows fed a variety of forages.
MATERIALS AND METHODS

Two lactating Holstein cows of similar body weight (501 and 471 kg) and milk production (23.6 and 23.4 kg 4% fat corrected milk) at the start of the trial, were utilized in a complete random design experiment to test four types of alfalfa forage. The experimental forages were: 1) low dry matter alfalfa haylage (LDMH, 38.7% DM, 17.8% CP, DM basis); 2) high dry matter alfalfa haylage (HDMH, 55.2% DM, 17.6% CP, DM basis); 3) alfalfa hay (AH, 85.0% DM, 17.5% CP, DM basis); and 4) alfalfa pellets (AP, 90.8% DM, 16.1% CP, DM basis). Each cow received a complete mixed ration consisting of one of the forages plus a grain mix consisting of 50.6% ground ear corn, 44.5% soybean meal plus minerals in a 3 to 1 (forage to grain) ratio (DM basis). Rations were mixed well prior to feeding to assure a complete mixture of forage and grain. The ration was offered twice daily to provide a 5 to 10% refusal. Refusals were obtained each day before the first feeding.

Animals were fed from experimental mangers which permitted recording of feed intake data. Mangers were suspended

1Minerals consist of 1% Dicalcium phosphate, 1% limestone, 0.5% salt, 0.2% magnesium oxide, 0.2% selenium premix, and 2.0% molasses.
on a single force transducer having a 114 kg capacity\(^2\). Each manger was connected to a transducer-demodulator\(^3\) in a nearby laboratory. Recordings were made with a 2 pen strip chart recorder\(^4\) over a 24 hr. period. The recorder was calibrated for linear changes with increasing weights. The precision of the instrument for weight changes was ± 50 grams. Mangers were constructed in a manner such that recordings were made only of eating bouts and not general body movement in experimental stalls.

Coincidental pressures on the manger during eating periods define the period of the eating bout and the amount of feed eaten was determined from the mean difference measured before and after an eating bout. Duration of each eating bout, amount (weight) of each bout, and intervals between eating bouts were calculated. The distribution of eating bouts were analyzed by 1) .25 kg increments up to 5 kg in weight, 2) 1 min. increments up to 10 min. in length, and 3) 1 min. increments up to 10 min. between bouts. Animals were allowed 10 days to adjust to each diet and were fed in the experimental mangers for a 5-day period. The last 4 days' data were used for analysis, allowing for a 1-day adjustment to the mangers. Animals were milked daily prior to each feeding. Aside from milking, other interferences affecting eating were kept at a minimum.

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\(^2\)Datronic Corporation, Miamisburg, Ohio.
\(^3\)Datronic Corporation, Miamisburg, Ohio, Model 201C.
\(^4\)Leeds Northrup Speedomax M, Mark II.
After establishing criteria to separate nibbling from meals, initial meals were separated from spontaneous meals and total meals were analyzed by least squares analysis of variance (12). Meal data were analyzed by a stepwise least squares analysis to determine the best model for characterizing feed intake data such as that obtained in these and similar studies. Meal data from these four forages were then analyzed by this model to determine differences.
RESULTS

Data collected from the four forages for all cow days were categorized according to length in time and weight of eating bout. The number of observations that fell into each time and weight category were summed by forage and plotted to show distribution. Eating bouts that were over 10 min. in duration, 5 kg in weight, or had an intermeal interval greater than 10 min. defined meal separations clearly and were not included in this data set. The number of eating bouts that are less than 10 min. in duration are represented in Figure 1. The number of eating bouts represented within each time category decrease with increasing time and stabilize by 5 min. in all diets. This would indicate that a large number of these short duration eating bouts are not individual meals but nibbling.

The intervals between eating bouts, as shown in Figure 2, describe much more variation than does the duration of eating bouts. The majority of short, interbout intervals, are less than 6 min. in length. The large number of short duration, between eating bout intervals, indicate that these are a set of homogeneous nibbling bouts or pauses within a larger meal, and separations should not be made.
Figure 1. Distribution of short-term eating bouts by length of time.
Figure 2. Distribution of between eating bout intervals by time.
The size of eating bouts in terms of weight of feed eaten, shown in Figure 3, depicts much more variation than does the previous figures. This indicated that eating bout size in terms of weight was the weakest criteria for describing meals of those given. In other terms, it has much less specificity and precision than length of bout in time and interbout interval for characterizing short meals.

A stepwise least squares analysis was carried out with the data set of meals in order to determine the significant main effects and interactions that should be included in the model to analyze meal pattern data. Terms found to be non-significant (P > .25) were included in the error term. The statistical model obtained follows:

\[ Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + e_{ijkl} \]

where \( Y_{ijkl} = \) observation of the \( i^{th} \) cow on the \( j^{th} \) feed on the \( k^{th} \) day and the \( e^{th} \) replicate

- \( \mu = \) population mean
- \( \alpha_i = \) effect of the \( i^{th} \) cow
- \( \beta_j = \) effect of the \( j^{th} \) feed
- \( \gamma_k = \) effect of the \( k^{th} \) day
- \( (\alpha\beta)_{ij} = \) effect of the \( i^{th} \) cow and the \( j^{th} \) feed
- \( (\alpha\gamma)_{ik} = \) effect of the \( i^{th} \) cow on the \( k^{th} \) day.

The day and feed effects vary according to experiment; however, the cow effect is highly significant in all cases along with the cow x day and cow x feed interactions.
Figure 3. Distribution of eating bouts by weight.
Using the defined criteria to establish a meal and the described statistical model, the data from the four forages were analyzed. Table 1 shows the average meal patterns for the four diets using the established criteria to define a meal. Differences were found in meal length and intermeal intervals.
Table 1. Meal patterns of lactating dairy cows eating various forages.

<table>
<thead>
<tr>
<th></th>
<th>LDMH</th>
<th>HDMH</th>
<th>AH</th>
<th>AP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length (min)</strong></td>
<td>18.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>32.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Size (kg as fed)</strong></td>
<td>1.50</td>
<td>1.62</td>
<td>1.43</td>
<td>1.37</td>
</tr>
<tr>
<td>(kg DM)</td>
<td>0.75</td>
<td>1.01</td>
<td>1.22</td>
<td>1.21</td>
</tr>
<tr>
<td><strong>Intermeal interval length (min)</strong></td>
<td>72.16&lt;sup&gt;x&lt;/sup&gt;</td>
<td>84.29&lt;sup&gt;x&lt;/sup&gt;</td>
<td>91.70&lt;sup&gt;x&lt;/sup&gt;</td>
<td>129.39&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Total intake kg DM/day</strong></td>
<td>11.82</td>
<td>11.28</td>
<td>12.00</td>
<td>11.91</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means with different superscripts are different, P<.000.
<sup>b</sup>Means with different superscripts are different, P<.067.
DISCUSSION

This investigation shows that criteria can be established that differentiates nibbling bouts from meals in lactating dairy cows fed complete mixed rations. In describing eating bouts in terms of length of time spent eating, a great majority of the short duration meals occur within 0 to 4 min. in duration. These can be termed nibbling bouts and not meals. They could be part of a larger meal also, but should not be considered a meal themselves. Beyond 5 min., meal duration is varied, the mean dependent upon diet and other factors.

A large number of the time intervals between eating bouts are less than 6 min. in length. This large number of between eating bout intervals indicate that they are nibbling bouts or short pauses within a meal, and therefore meal separations should not be made. Previous work has shown the eating behavior of dairy cows often require them to masticate their food for a short time before continuing to eat (13).

The size of eating bouts shown in Figure 3 is much more varied and does not show a separation of nibbling and meals at these higher levels of intake (>1 kg). The duration of eating bout and interval between bouts are more precise indicators of meals than weight of feed eaten. Perhaps the
criteria of weight determinations used to base a meal would be 2x the sensitivity of the equipment along with the duration and between meal criteria already established.

Analysis of the data for the four diets show that the animals ate for a longer period of time on the alfalfa hay diets and that there were larger intermeal intervals on the alfalfa pellet diets. This follows previous work (10,13) that the physical form and dry matter content of a diet may affect eating rates. The great variations in meal size prohibiting any significant differences to be observed, again show that this parameter is perhaps the weakest of those tested, to determine meal patterns. When meal size is converted to dry basis, the size of the silage meals are smaller than either the hay or pellet meals. Total dry matter intake for all diets were similar, however, appeared somewhat low (2.33 to 2.50% of body weight). These low levels were accounted for by the low production maintained throughout this experiment as both cows were in the last third of lactation and experienced many diet changes throughout the study.

Feed intake behavior is a very complex field that is deserving of much study. Many factors such as fill, energy density of the ration and digestibility must be considered as well as the energy demand of the particular animal, when studying feed intake behavior.
LIST OF REFERENCES


