GRAZING AND FEEDING MANAGEMENT OF LACTATING DAIRY COWS

by

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(ABSTRACT)

Two studies were conducted during the grazing season of 1997. Study 1 consisted of three Experiments, and the objectives were to compare milk production and composition, body weight change and body condition score, and to determine time patterns of grazing between cows supplemented with different forms and amounts of corn. Also rumen fermentation parameters were measured in cows supplemented with two different types of corn. In study 2, milk yield was measured when grazing pasture was supplemented to lactating Holstein cows fed a typical TMR diet. Predominantly orchardgrass pastures with lesser amounts of white clover and Kentucky bluegrass were grazed during both studies. In Experiment 1, 36 Holstein cows were supplemented either with 6, 6, 6, or 4 kg/d DM of high moisture corn, coarsely ground corn, finely ground corn, or high moisture corn in two equal feedings, respectively. Milk yield was similar (30.3 kg/d) among treatments. Milk protein (2.97%) and MUN (14.7 mg/dl) did not differ among treatments. Body weight change and body condition score change were similar among treatments (23.1 kg and -0.24). During Experiment 2, four rumen-cannulated cows in mid-lactation were supplemented 6 kg/d DM of either coarsely ground corn or high moisture corn in two equal feedings. After the p.m. milking, ruminal pH was measured and rumen fluid samples were collected to determine ammonia N and VFA. While grazing, this was repeated at 0.5, 1, 2, 3, …8 h post-corn feeding (0 h). Ruminal pH was similar for both corn supplements and was lowest (5.9 and 5.8) at 5 and 8 h, respectively. Rumen ammonia N concentrations started to increase approximately 2 h after cows began grazing, reaching maximum levels 5 h later. In Experiment 3, the number of cows grazing, lying, or standing were recorded every half hour, for two consecutive days, while grazing. Cows grazed an average of 6.4 h/d, 4.1 h in the afternoon and 2.3 h in the morning. Similarity in milk production, milk composition, BW change, and BCS between treatments indicates that the quality and availability of pasture permitted equal response regardless of the type or amount of corn supplemented. Fifty four Holstein cows in mid lactation were used in Study 2. Cows were fed either a TMR diet only, or were fed TMR during half of the day (after the a.m. or p.m. milking according to the treatment) and supplemented with grazing pasture during the other half of the day. Milk production was slightly but significantly higher for cows on the TMR treatment (29.1 vs. 28.2 and 27.6). No significant difference between treatments was observed in FCM (27.7 kg/d), and milk fat (3.47) and protein percentage (3.23). While BW change did not differ among treatments (25.7 kg), body condition score increased more in cows fed only a TMR diet (0.14 vs. -0.06 and 0.01). The TMR intake was significantly different between treatments, being highest for cows on the TMR treatment and lowest for cows grazing after the p.m. milking (26.6 vs. 20.3 vs. 17.5 kg/d DM). Income over feed cost differed between treatments, and was approximately 15.3% higher for cows supplemented with high quality pasture during the afternoon compared to cows on TMR. Dairy farmers may obtain economical benefits by practicing this type of management during the grazing season with little effect on milk yield.

DEDICATION

I dedicate this thesis to my wife Cecilia, for her love, help, and support; and to my parents, Diego and Yaya, for their unconditional support and for encouraging me to pursue a graduate degree.

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CHAPTER I

INTRODUCTION

Using pastures as the major source of nutrients for lactating cows is widely practiced in countries like Argentina, Australia, and New Zealand, but has varied considerably in the US. In the early 1950's, pasture provided over 30% of the nutrients dairy cattle consumed (Ball et al., 1996). However, grazing declined steadily from 1950 to 1980 (Ball et al., 1996). In the 1980's several factors induced the resurgence of interest in the adoption of grazing in small dairy farms (Parker et al., 1992). Economic advantages of intensive grazing over a conventional dry-lot system during the grazing season have been demonstrated by several surveys and research trials (Parker et al., 1992; Holden et al., 1994b; Hanson et al., 1998). Thus, smaller dairies with sufficient land resources can make valuable use of high quality pastures.

Energy is usually the primary limiting nutrient when lactating dairy cows graze high quality pastures (Kolver and Muller, 1998). Extensive research has been conducted at Virginia Tech and Pennsylvania State University with the objective of determining the ideal amount of concentrate to be supplemented for high producing dairy cows (Polan et al., 1986; Hoffman et al., 1993; Holden et al., 1994b; Polan, 1997). Results from these studies suggest that supplementing more than 8 kg/d of dry corn will have little or no effect in cow performance when enough herbage is available.

Limited information is available on the rumen fermentation parameters of grazing cows (Berzaghi et al., 1996; Holden et al., 1994a). Furthermore, no research has been conducted to compare the effects on rumen fermentation and milk production and composition of different forms of corn supplemented to grazing dairy cows. Thus, the objectives of the first study were to compare cow performance when different forms and amounts of corn were supplemented to lactating Holstein cows grazing predominantly orchardgrass pastures. In the same study, the rumen fermentation parameters of grazing cows fed the same amount (6 kg/d DM) of either dry corn or high moisture corn was compared.

In order to obtain optimal performance of grazing high producing dairy cows, it is also important to understand the grazing and feeding behavior of these animals. Herbage abundance, ambient temperature, and grazing pressure are within the most important factors affecting the grazing behavior of ruminant animals. However, no research has been conducted in the US to determine duration and moment of the day in which intensive grazing activity occurs. Thus, during Experiment 3 of the first study, grazing patterns of lactating dairy cows were observed.

Lack of confidence in diets based on pasture is the most common reason why dairy farmers do not adopt intensive grazing (Parker et al, 1992). Thus, a transition period between confinement and intensive grazing during the grazing season may have positive results for some dairy farmers. In the second study the feasibility of feeding a TMR diet supplemented with grazing high quality pasture was evaluated. Cow performance and income over feed cost were compared for cows in confinement during the 24 h versus cows fed TMR during half of the day, and grazing high quality pasture during the other half of the day (either during the morning or afternoon).

CHAPTER 2

REVIEW OF LITERATURE

Intensive Rotational Grazing

Rotational grazing is a grazing management system in which the total pasture area is subdivided into several paddocks which are grazed sequentially. For each subdivided area, a rest period follows each grazing cycle. The number of paddocks may vary from only a few to 12 or more, and a high stocking rate is imposed on a paddock for a short time, often 1 or 2 days (Ball et al., 1996).

Several researchers (Voisin, 1988), (Baker, 1986a), (McMeekan and Walshe, 1963), (Holmes, 1980a), (Hoden et al., 1991), (Arriaga-Jordan and Holmes, 1986), (Walker and Heitschmidt, 1989) have been studying rotational grazing for the past 38 years. Reasons for using intensive rotational grazing were first described by Voisin in 1959. He said that livestock should occupy a paddock only for a short period, since animals might otherwise defoliate a plant twice. Second, there should be sufficient interval between grazings to replenish reserves of labile carbohydrates in the roots and crown and to develop leaf area to intercept radiation (Voisin, 1988). By adopting intensive rotational grazing, grazing pressure can be controlled and less forage will be wasted (Van Soest, 1994a). Furthermore, increasing grazing pressure will give significant improvements in pasture utilization, milk production, and gross margins per hectare (Baker, 1986).

Finally, Crowder (1985) suggests that rotational grazing is suited to intensive utilization of improved pastures and is designed to obtain more uniform grazing than the continuous system does.

Stocking rate

Mott (1960) considered the stocking rate as the most important factor influencing milk output per cow and per unit area. Furthermore, Holmes (1980a) concluded that although milk yield per head may decrease as stocking rate is increased, this will not necessarily be uneconomic, provided yield per hectare continues to increase. Fales et al. (1995) compared a low (2.5 cows/ha), moderate (3.2 cows/ha), and high (4.0 cows/ha) stocking rate in lactating dairy cows during two consecutive grazing seasons. Results showed that an increase in the stocking rate of 37.5 % (2.5 vs. 4.0 cows/ha) led to an increase in milk yield/ha of 38 %. An economic analysis indicated that profits per unit area of land increased with stocking rate, showing a $1190/ha advantage for the high stocking rate compared to the low stocking rate. Furthermore, stocking rate had a positive effect on pasture nutritional quality and had a negative relationship with the percentage of the pasture rejected by cows. These findings are in agreement with other studies (Holmes, 1989), (Mayne, 1987), (Hoden, 1991) and shows that high stocking rates may result in optimal pasture and management conditions.

Herbage Mass Determination

In grazing studies where pastures are the main constituent of the diet, estimates of herbage mass should be determined for rationing purposes when the stocking rate is fixed, or for adjustment of stocking rate when a fixed grazing pressure is desired (Vartha and Matches, 1977). The first measurements of herbage mass were probably made by Sinclair in 1816, who cut and weighed hay and aftermath from small plots of various grasses and legumes (Frame, 1981). Frame (1981) classified the methods for herbage mass estimation as direct (clipping) and indirect (height measurement):

Direct method of herbage mass determination

Dry matter (DM) has become the conventional basis of expression of herbage mass. Whatever the objective or type of trial, the basic operation is to cut and measure a sample of fresh herbage of a predetermined size and shape, and at a specified height. After collection and weighing, the complete sample is oven-dried, and DM is obtained (Frame, 1981). Drying is necessary since the amount of moisture in the herbage (usually 75-85 %) depends upon the stage of growth, plant species and variety, fertilizer nitrogen use, and the amount of external water in the form of rain. In practice, the number of samples taken will be largely determined by the number that can be handled with the resources and time available. Although general recommendations for the number of samples required cannot be made, many reports feature between 5 and 12 sub-samples per plot (Frame, 1981).

Cutting and weighing is the most accurate method of estimating forage yield. But cutting is costly, in terms of time and labor, and may influence production and composition of forage as well as grazing behavior (Bransby et al., 1977). Therefore, a rapid, indirect, in situ, non-destructive technique for making accurate estimates of pasture DM yield would benefit grazing trials (Bransby et al., 1977).

Indirect method of herbage mass determination

Forage bulk may be regarded as a combination of forage attributes (a function of forage height, density, and compressibility) and as such, can be measured with a single device (Bransby et al., 1977), like the weighed-disk instrument. Thus, sward height has been recognized to be a useful index of sward conditions (sward bulk density) (Baker, 1986).

The use of the weighed-disk instrument for estimating dry matter available on grazed pastures has been described by Castle (1976), Bransby et al. (1977), Vartha and Matches (1977), Frame (1981), Baker (1986), Kanneganti and Kaffka (1995), and Murphy et al. (1995). This disk, normally consists of an aluminum (Bransby et al., 1977), (Castle, 1976), (Frame, 1981) or thick acrylic (Rayburn, 1994a), (Murphy et al., 1995) plate, which fits over a stem or rod held in a vertical position with its base at ground level. When the plate is allowed to rest on the sward, the instrument readings are influenced by a combination of sward height and density; and the readings are calibrated against herbage mass measured by cutting (Frame 1981).

The first correlations between compressed sward height and herbage dry matter content (0.39-0.62) obtained from clippings were reported by Castle (1976). These were low correlations compared to those reported (0.7-0.94) by Bransby et al. (1977) and Vartha and Matches (1977) in tall fescue (*Festuca arundinacea*) swards. Correlations were also reported in mixed pastures of white clover (*Trifolium repens*) and perennial ryegrass (*Lolium perenne*) of 0.97 (Stockdale and Kelly, 1984), in grass-legume pastures of 0.88 (Rayburn, 1994a), and in other grass species of 0.84-0.92 and 0.72 by Stockdale and Kelly (1984) and Murphy et al. (1995), respectively.

Therefore, indirect, non-destructive methods, like the weighed-disk instrument or height estimate, can be used by farmers and pasture researchers for a quick, simple, and accurate estimation of herbage mass, for adjusting stocking density (Baker, 1986), and as an indicator for supplementary feeding (Leaver, 1982).

In conclusion, intensive rotational grazing is probably the most appropriate grazing system for lactating dairy cows. Pastures can be utilized more efficiently with this type of system as compared to a more extensive or continuous grazing. Furthermore, relatively frequent measurements of sward height (approximately twice per week, depending on plot area) can be a relatively accurate method to determine the amount of pasture dry matter offered daily. This type of indirect, non-destructive method has to be calibrated at least once a month in order to maintain accuracy of herbage mass estimation.

The Feeding Value of Pasture

The feeding value of a forage can be defined as the product of available nutrients contained in the forage (nutritive value) times the amount of forage consumed (voluntary intake) (Holmes, 1980b). Leafiness and stage of growth are factors that will affect the feeding value of plants. High leaf content is associated with a low proportion of cell wall constituents and a high proportion of cell contents. According to Munro and Walters (1981) the main effect of advancing maturity in grasses is an increased proportion of cell wall (mainly hemicellulose, cellulose, and lignin) and a reduction of cell contents. Feeding value will also vary within the same grazing season and among forage species. Among the climatic variables, light and temperature are the most important, followed by moisture (VanSoest, 1994b). Results reported by Polan (1997); Harris et al. (1997); Beever and Thorp (1996); Thomson et al. (1985); and

Ulyatt et al. (1988) suggest that in general, feeding value of legume species is higher than grass species.

Normally, animal production will depend on the ability of the herbage to provide energy, provided that protein, minerals, vitamins, and water are consumed in sufficient amounts to sustain the type of production sought (Ulyatt, 1973).

The chemical constituents of pasture

From a nutritional stand point, plant material can be divided into the cell contents fraction (organic acids, soluble carbohydrates, crude protein, fats, and soluble ash) and the cell wall fraction (hemicellulose, cellulose, lignin, cutin, and silica) (Minson, 1990a). The cell contents are usually highly digestible and readily available in the rumen. On the other hand, the availability of plant cell walls varies greatly depending on their composition and structure (Buxton et al., 1996). Maturity or stage of growth, species, and environmental factors can affect the chemical composition of herbage plants (Holmes, 1980b). As plants mature, the proportion of cell wall and its constituent fractions increase and the cell content fraction decrease. An exception is non-structural carbohydrates , mainly fructans, which increase in stem, stem base, and inflorescens (Holmes, 1980b).

Furthermore, cool season grasses will normally have a higher cell wall concentration than legumes, especially in leaves, but a lower cell wall concentration compared to warm season grasses (Buxton et al., 1996).

Crude protein. Mangan (1982) classified plants crude protein (CP) in three main groups. Fraction I (leaf protein), Fraction II, and chloroplast membrane proteins. Fraction I is composed of chloroplasts which contain about 75% of the total leaf protein and of this, about 50% is a single soluble protein (ribulose-1, 5-bisphosphate carboxylase). Mangan (1982) reported mean values for Fraction I of 5.3, 3.9, and 0.9 % for alfalfa (*Medicago sativa*), red clover (*Trifolium pratensis*), and orchardgrass (*Dactylis glomerata*), respectively. On average, 70% of the true protein (TP) of cool season forage plants can be accounted for by Fraction I. Furthermore, Fraction I protein is very similar across plant species (e.g. grasses and legumes), and is very rapidly degraded in the rumen (Nugent and Mangan, 1981). Fraction II constitutes about 25% of total leaf protein, and is derived both from chloroplasts and the cytoplasm. In contrast to Fraction I, this is a very complex mixture, which may have a low rate of proteolysis and could result in a high proportion passing through the rumen undegraded (Thomson, 1982).

The third fraction is constituted of chloroplast membrane proteins. This protein is insoluble in water and constitutes about 40% of the chloroplast protein (Mangan, 1982). The chloroplast membrane protein can be divided into two main chlorophyll-protein complexes, chlorophyll-protein complex I and chlorophyll-protein complex II, which account for 28 and 49% of the membrane protein, respectively. These chlorophyll-protein complexes appear to be slowly degraded in the rumen, although this has not been investigated (Mangan, 1982).

Cell walls contain a cell wall associated protein called extensin due to their probable role in fiber cross-linking. This protein is much less soluble than leaf proteins and are recovered in neutral detergent fiber (NDF). Extensins are probably covalently linked to polysaccharides associated with the plant cell wall, which may account for their insolubility (Van Soest, 1994c). Although the concentration of N in cell walls is lower in grasses than in legumes, N in cell walls accounts for a higher proportion of total N in grass leaves than in legume leaves because of the higher cell wall concentration in grass than in legumes (Buxton et al., 1996). Sanderson and

Wedin (1989) reported N concentrations in leaf cell walls of alfalfa, red clover, and smooth bromegrass to be 9.8, 26.4, and 6.4 g/kg NDF, respectively, and 4.2, 4.6, and 2.4 g/kg NDF for stems, respectively.

Nucleic acids, free AA, amides, and nitrate constitute most of the non-protein N (NPN) (Buxton et al., 1996). About 15 to 20% of the soluble N of herbage samples consists of free AA (Mangan, 1982). Aspargine is usually the predominant free AA in legumes, and glutamine in grasses (Mangan, 1982). Another important constituent of the NPN fraction in plants is nitrate, which has great fluctuation during the growing season. Accumulation of nitrate readily occurs under conditions of high temperature and low light (Mangan, 1982), which reduces plant metabolism.

Proteins can also be classified according to their nutritional characteristics into soluble protein (SP), rumen degradable protein (RDP), and rumen undegradable protein (RUP). Most of the CP of fresh forage is degraded in the rumen, with only 25% (on average) CP passing unchanged into the small intestine (Minson, 1990b). Examples of values of CP, and rumen degradable (RDP) and undegradable (RUP) protein reported from pasture samples obtained from the states of Virginia, Pennsylvania, New York, Maine, New Hampshire, and Vermont are shown in Table 2.1. In the same table, data from Polan (1997) and Rayburn (1994b) show the differences in CP content between legumes and grasses under the same environmental conditions.

In conclusion, true protein makes up about 60 to 80% of the total plant N, with soluble NPN and a small amount of lignified N making up most of the remainder (Van Soest, 1994c). Furthermore, amino acid composition of the protein extracted from leaves of grasses and legumes is remarkably constant (Holmes, 1980b). Data of the AA profile of grass, legume, and mixed pastures reported in Table 2.2 confirms this statement.

Carbohydrates. When classifying plant carbohydrates, plant physiologists emphasize biosynthesis, while nutritionists emphasize biodegradation (Van Soest, 1994d). From the nutritionist point of view, carbohydrate content in plants can be classified in two major components; non-structural carbohydrates (NSC) and structural carbohydrates (SC).

Non-structural carbohydrates. Non-structural carbohydrates are rapidly and completely digested in the rumen, and therefore, they are readily available sources of energy to ruminant animals. Non-structural carbohydrates are composed of water soluble carbohydrates, fructans, starch (all form part of the cell content), and pectins. The latter are part of the cell wall structure, but are also rapidly and extensively degraded in the rumen (Hall, 1994). A slightly different classification of carbohydrates was suggested by Mertens (1992) to describe their nutritional characteristics; this is fiber (FC) and non-fiber carbohydrates (NFC).

The water soluble carbohydrates represent the more rapidly digestible part of the NFC of the plant. This fraction includes glucose, fructose, sucrose, and trace amounts of melibiose, raffinose, and stachyose (Smith, 1973). On average, glucose and fructose occur in about a 1:1 ratio and in a magnitude of 1 to 3% of forage DM. Sucrose occurs in larger amounts than the monomers, in the order of 2 to 8% DM (Smith, 1973). Smith also reported values of sucrose of 2.8 and 5.2 % of DM when orchardgrass and ryegrass, respectively, reached a height of 20-25 cm.

Fructosans are fructose polymers that contain a terminal glucose residue (Smith, 1973), and are the main storage carbohydrates in leaves and stems of temperate grasses (0.6-5.4% of herbage DM). They do not occur in legumes or tropical grasses where sucrose and starch are the main reserve carbohydrates (Van Soest, 1985). Fructosans are completely digestible and are partially water soluble.

Starch is the primary non-structural polysaccharide in species of the Leguminoseae (Smith, 1973). Smith (1973) reported values of starch of 8.7, 8.6, and 7.4% DM during the vegetative stage of alfalfa, red clover, and white clover, respectively, and showed that amylopectin was the predominant starch found in alfalfa leaflets.

Pectin, although a constituent of the plant cell wall, is a soluble carbohydrate (Van Soest, 1994d; Hall, 1994). Therefore, as mentioned before in this chapter, it is a component of the NFC fraction in plants. This polysaccharide has no bonding with lignin, even with increasing plant maturity (Hall, 1994), thus it is dissolved in neutral detergent solution. Grasses are low in pectin (2-5% DM) while legumes contain the highest quantities (6-14% DM) (Hall, 1994). Examples of NFC content are shown in Table 2.3 of pastures from the states of Virginia, Pennsylvania, Maine, New York, New Hampshire, and Vermont.

Sugar content of forages is also markedly affected by environmental growth conditions. High light intensity and photosynthetic rate increase sugar content (especially sucrose), and high temperature promote increased metabolic rate and lower sugar content (Van Soest, 1994d). Consequently, marked diurnal variations in sugar content occur in living plants, being lowest during early morning and highest in late afternoon.

Structural carbohydrates. Structural carbohydrates or fiber carbohydrates (FC) are components of the plant cell wall. As mentioned before, the main components of FC are cellulose, hemicellulose, and a non-carbohydrate fraction, lignin.

Cellulose is the most abundant carbohydrate in the plant, but its amount or concentration is not a good measure of fibrousness or total fiber, although many nutritionists have used it for this purpose (Van Soest, 1994d). It has a highly variable nutritive availability depending on its association with lignin, silica, cutin, and other factors (Van Soest, 1985). Van Soest (1971) reported average values for cellulose of 22.0, 22.9, and 18.7 % DM for grasses, alfalfa, and red clover.

Hemicellulose is an heterogeneous polysaccharide fraction largely existing in the secondary wall of the plant. It is more soluble in acids and bases than cellulose, but not more digestible (Van Soest, 1985). Digestibility of hemicellulose is directly related with that of cellulose and inversely related to lignification (Van Soest, 1994d). These polysaccharides vary according to grazing season and plant stage of maturity. Bailey (1973) reported changes due to seasonal variations for ryegrass and orchardgrass of 12 to 20% for hemicellulose and 14 to 24-28% for cellulose. He suggested that variations were probably due to increasing amounts of stem tissue. Little changes in the level of leaf and stem hemicellulose content occur in legumes during growth; however, a marked rise in stem cellulose usually results from increasing amounts of stem tissue (Bailey, 1973). Thus, in general, cool season grasses will contain higher concentrations of hemicellulose than legumes (Table 2.3).

Lignin, a non-carbohydrate polymer, is another component of plant cell wall and is most often identified as limiting cell wall polysaccharide digestibility by ruminants (Buxton et al., 1996). Lignin is covalently bound to cell wall polysaccharides, but until recently little was known about the form of this cross-linkage (Jung, 1997). When the plant cell stops growing and initiates the maturation process, secondary wall deposition and lignification begin. Lignin deposition begins in the primary wall, and then progressively moves through the secondary wall

(Jung and Allen, 1995). Lignin concentration is generally lower in grass cell walls than in legume cell walls, but it can comprise up to 10% of DM in nearly mature cool season grasses (Buxton et al., 1996).

From a nutritional stand point FC can be measured by determining the neutral detergent fiber (NDF). The extraction of forages showed that NDF separated the potentially completely available matter from that which is insoluble or incompletely or partially digestible (Van Soest, 1993). Thus, NDF is consistent in representing the insoluble coarse fiber from forages that stimulates rumination and rumen function, which are vital to maintenance of the rumen ecosystem (Van Soest, 1993). Furthermore, the acid detergent fiber (ADF) was intended to isolate the components more resistant to digestion.

Table 2.3 shows NDF values for grass, legume, and mixed pastures from a number of Eastern States. In general, grasses contain higher levels of fiber (NDF) than legumes, confirmed by the NDF values reported by Polan (1997) and Rayburn (1994b) on legume and grass pastures (Table 2.3). Although this is true it does not mean that legumes are more digestible than grasses, since Buxton and Redfean (1997) demonstrated that legume fiber is more lignified and less digestible than that of grasses. Therefore, the reason why typically legumes are more digestible than grasses is because they contain less fiber (NDF), not because legume fiber is more digestible (Buxton and Redfean, 1997). Buxton et al. (1996) determined that depending on maturity, ruminants will digest 40-50% of NDF in legumes and 60-70% in cool season grasses.

Minerals. The mineral elements constitute some 10% of herbage DM. Soil is the primary source of supply of mineral elements to the plant, and as such, it is considered to be the main factor affecting mineral content in plants. Plant (genus, species, variety, and stage of maturity), environmental (light, temperature, and season), and management factors, like fertilization will also affect mineral concentrations in pastures (Fleming, 1973; Mayland and Wilkinson, 1996).

In general, at early growth stages there is a relatively rapid uptake of minerals. As photosynthetic areas begin to increase, DM production outstrips mineral uptake with the result that, due to a natural dilution process, mineral contents decline (Fleming, 1973).

The National Research Council (1989) (NRC) recognizes calcium (Ca), phosphorus (P), sodium (Na), chloride (Cl), potassium (K), magnesium (Mg), and sulfur (S) as the essential macro minerals.

In this chapter, more emphasis will be given to Ca, P, K, and Mg. Herbage content of mineral nutrients are shown in Table 2.4. This data gives only a general indication of the complex interrelationships involved in adequate mineral nutrition of livestock. Thus, in addition to information on herbage mineral levels, other considerations important to mineral nutrition of grazing animals are direct soil ingestion and the availability of minerals (Butler and Jones, 1973).

Calcium. Chronic Ca deficiency in ruminants fed grass is very rare and never occurs in legume-based pastures (Minson, 1990c), with the possible exception of high milk producing dairy cows (Buxton et al., 1996). Generally cool-season grasses contain less Ca than legumes. Average calcium concentration from data obtained from Muller et al. (1995), Rayburn (1994b), Fleming (1973), Powell et al. (1978), NRC (1989), and Minson (1990c) was of 0.49 and 1.58 % of DM for grasses and legumes respectively (Table 2.4). As forage matures there is an increase in the proportion of stem, which generally contains less Ca than the leaf fraction (Minson, 1990c). Therefore, Ca concentrations will decrease as the plant matures.

Availability of herbage minerals has been little studied largely due to the considerable difficulties inherent to its assessment (Butler and Jones, 1973). Availability of Ca in feeds depend on the needs of the animal and is rarely limited by a characteristic of the forage except where oxalate levels are high. Many of the estimates for availability quoted in the literature are of apparent availability. Apparent availability of 0.3 to 0.4 are commonly reported for Ca, P, and Mg in herbage, but true availability (accounting for endogenous losses) are considerably higher (Holmes, 1980b). Even when true availability is determined, the data require careful interpretation, as the availability of Ca is also influenced by level of intake, and the values may only therefore apply to the feeding conditions of the particular experiment (Butler and Jones, 1973). For example, Minson (1990c) reported a study where lambs, which have a high requirement for Ca, absorbed 70% of Ca in a synthetic diet with a low level of Ca but only 40% when the Ca level was high.

Notable changes in Ca recommendations occurred from NRC (1978) to NRC (1989). This was primarily due to changes in the absorption coefficient used to calculate requirements, which changed from 0.45 to 0.38 (Beede et al., 1992). This resulted in higher estimated daily requirements in the later NRC (1989). In contrast, the ARC (1980) resolved that 68% of the Ca in most cattle feeds was available for absorption. The NRC (1989) may include safety margins, but ARC values have no added safety margins (McDowell, 1985a).

In conclusion the figures for available Ca do not represent the potential availability of Ca in forages and it is probable that the published Ca requirements (NRC, 1989) of ruminants are overestimated.

Phosphorus. Phosphorus in herbage appears to be more available than Ca (Butler and Jones, 1973). Unlike Ca, the quantity of dietary P absorbed from the upper small intestine is directly related to the quantity of P in the diet and is not related to the need for P (Braithwaite, 1976). In contrast, NRC (1989) reported that absorption of P will vary with age of the animal, decreasing the efficiency at about 14 months of age. Thus, the estimated requirements are based on a decline in the availability of P from about 90% in calves to 55% in animals with live weight of over 400 kg.

In the 1980 revision of nutrient requirements of ruminant livestock, the ARC (1980) committee substantially reduced its estimates of the P requirements of cattle, with the exception of the high-producing Jersey cow. Yet other studies suggest that the values should be increased (NRC, 1989). Therefore, an absorption coefficient of 0.5 was used to calculate the requirements in the NRC (1989). This generally resulted in a 10 to 22% increase in daily requirements of P compared to earlier estimates (NRC, 1978). It must be remembered, however, that this absorption coefficient is based on a minimum endogenous fecal loss of 14.3 mg/kg of body weight. Thus, the fact that the minimum endogenous loss is not a constant, but varies with the efficiency of absorption could invalidate this procedure (Field, 1983).

Phosphorus concentrations in different types of pastures are shown in Table 2.4. Typically grasses have lower contents of P compared to legumes. Good examples of this are the values reported by Muller et al. (1995) and Rayburn (1994b). However, the total average P content of all references included in Table 2.4 is not different between grasses and legumes. This shows that not only differences between species will determine mineral concentrations in plants, but also other factors like soil fertility.

Magnesium and potassium. In general legumes are appreciably higher in magnesium (Mg) concentration compared to grasses (Grumes, 1983; Fleming, 1983; Fleming, 1973; Minson, 1990d; McDowell, 1985b). Table 2.4 show ranges of Mg concentration of 0.15 to 0.31 and 0.30 to 0.55 in grasses and legumes respectively. Recommendations on Mg requirements of different classes of livestock are complicated due to considerably uncertainty regarding the availability of Mg in the diet (Reid, 1983). Magnesium availability in pastures is lower than in concentrates and preserved forages (NRC, 1989; Reid, 1983). In sharp contrast to most nutrients, net Mg absorption is lowest from young, highly succulent pastures, and increases with forage maturity (NRC, 1989). Thus, efficiencies of Mg absorption in forages ranged from 7-33 and 5-30% DM as reported by Reid (1983) and McDowell (1985b), respectively.

The ARC (1980) calculated dietary requirements for dairy cows assuming an average Mg availability of 20%, and the suggested daily allowance ranged from 0.18 to 0.40% of total DM according to milk production and type of diet. Under grazing situations where most of the animal's nutrients come from lush, highly fertilized pastures, and for high-producing lactating cows in early lactation, the suggested requirements range from 0.25 to 0.30% of the diet (NRC, 1989). Under these situations, the NRC (1989) also recommended some supplemental Mg in a readily available form be provided, such as magnesium oxide (MgO).

A deficiency of Mg can depress production in two ways: by an acute deficiency leading to hypomagnesemic tetany or by a chronic subclinical deficiency like a decrease in milk production. In New Zealand, milk production of mature cows was depressed by a subclinical deficiency of Mg. In the first two months of lactation dosing with 25 g of Mg in the form of MgO increased milk production of cows on temperate pastures by 15 to 20% (Minson, 1990d). In similar studies where a TMR diet was fed (O'Connor et al., 1988; Teh et al., 1985), milk production increased 5.2 and 9% respectively, when dietary Mg was increased from 0.26 to 0.48 and 0.22 to 0.45% DM, respectively. Furthermore, positive responses in milk fat concentration and fat yield were reported by Emery (1983), O'Connor et al. (1988), and Teh et al. (1985) when MgO was added to the diet.

The disorder of hypomagnesemia is less likely to occur if the herbage contains over 0.20% Mg. However, the balance of other constituents such as K also influence the incidence of hypomagnesemia (Butler and Jones, 1973). While some workers would suggest that total N also induces grass tetany (Butler and Jones, 1973), others did not observe an induced hypomagnesemia when N was added to the ration in the form of NPN (Moore et al., 1972; Kemp, 1983).

Potassium, like almost all nutrients in plants decrease in content with maturity (McDowell, 1985b). The NRC (1989) reported that young, lush forages in cool weather may be extremely high in this mineral (often constituting about 3% DM). This is especially true for good quality grass and mixed pastures (Table 2.4).

According to the NRC (1989) and Ward (1966), the high levels of K in such pastures appear to interfere with Mg metabolism and utilization, and are considered to be a factor in grass tetany of lactating cattle. This is supported by several studies (Newton et al., 1972; Poe et al., 1985; Minson, 1990d; Fontenot et al., 1960; Kemp, 1983), where it was demonstrated that feeding high levels of K depressed absorption of Mg in the rumen stomach. Therefore, when diets are based on young, lush pastures rich in N (> 3.2-4% DM) and K (> 3% DM) a minimum of 0.3% Mg in the diet is recommended by Grumes (1983).

In conclusion, minerals will be abundant in pasture forages (with the exception of Mg), especially when legumes are present. Therefore, a balanced mineral mixture fed as part of the supplement or available free choice with salt will probably meet nutritional needs of lactating cows. In addition, MgO should be added to the diet in order to increase Mg levels to 0.35-0.40% of DM in the diet.

Soil contamination of pasture. Pasture plants grow close to the soil and are subject to soil contamination, resulting from the effects of trampling by grazing animals, rain splash or wind (Healy, 1973). Values of soil contamination of up to 6.8% DM were reported by Healy (1973), who concluded that contamination will rarely be in excess of 15-20% DM.

Thus, grazing animals ingest soil along with pasture because it adheres to the leaves of herbage (Grace et al., 1996). Dairy cows in New Zealand have been shown to ingest between 150 to 650 kg of soil per year. During the spring and fall, intakes were up to about 1 kg/d with 0.5 kg/d in summer (Healy, 1973). As the selenium (Se), copper (Cu), and iron (Fe) concentrations of soil can be 14 to 20 times that of pasture, the ingested soil could be an important source of trace elements (Healy, 1973). However, because of the nature of soil-trace element interactions, only a variable fraction of the ingested trace elements may be absorbed (Grace et al., 1996).

In a study conducted by Grace et al. (1996), Se concentrations in liver of sheep fed alfalfa pellets were lower (119 μg/kg dry weight) than concentrations in sheep fed alfalfa pellets plus two different types of soil (158 and 182 μg/kg dry weight). Further, this was associated with a 20-30% increase in plasma concentration of Se when soil was added to the diet. In contrast, no differences in Cu concentrations were found between treatments. In a similar study, Healy (1973) doubled the intake of Se and Fe using soil-contaminated pastures. These studies demonstrate that soil can be a source of trace elements like Se and Fe for grazing dairy cows.

Digestibility of pastures

Measurement of digestibility is one of the first important steps in evaluation of forage quality. Digestibility is the proportion of food consumed which disappears in the digestive tract and as such defines quantitatively the nutrient availability per unit of feed intake. For this reason it is a major component of nutritive value (Thompson and Poppi, 1990). In contrast, Van Soest (1965) considers that chemical composition is what determines the nutritive value of forages, as digestibility is dependent upon the proportion of the total forage made up by the soluble part and the lignification of the fibrous residue. Plant cell contents are almost 100% digestible, whereas cell wall digestibility varies with lignification and rate of digestion of cell walls.

Berzaghi et al. (1996) compared digestibility of diets based on pasture either with or without supplementation of 5.4 kg of cracked dry corn. Four lactating multiparous Holstein cows grazed mixed pastures during the study. Total OM (71.9 vs. 69.9%) and rumen true digestibility (64.3 vs. 58.7%) were higher when cows were not supplemented with corn. In contrast, rumen OM digestibility as a percentage of total tract digestibility was not different between diets (68.1 vs. 62.3%). This suggests that site of digestion might have shifted from the rumen to the duodenum due to the greater passage of undigested starch in cows that were supplemented with corn (Berzaghi et al., 1996).

In general, legumes are typically more digestible than grasses (Buxton and Redfear, 1997). This was corroborated by Steg et al. (1994) by comparing the OM digestibility between ryegrass and white clover at two maturity stages (early and late vegetative stage). On average, the undegradable fraction of OM was lower for white clover than for ryegrass (13.5 vs. 17% OM). For all forages, undegradability increased as the growing season progressed.

In contrast, rumen degradation of NDF was significantly higher for grasses than for clover (82 vs. 77%). Buxton and Redfear (1997) also reported lower values of rumen NDF degradation for legumes. Depending on maturity, ranges for NDF digestibility were 40-50% of NDF in legumes and 60-70% in cool season grasses.

Pasture digestibility was compared with hay and silage digestibility by Holden et al. (1994a). Forages were based on orchardgrass, and less amounts of Kentucky bluegrass and smooth bromegrass. True DM digestibility was 30% higher for pasture (73.7%) than for hay (56.0%) or silage (56.9%). Holden suggested that although grass harvested for hay and silage was visibly more mature than the grazed pasture, it was more likely that the digestibility of pasture was higher due to a higher content of NFC (30.5% DM) in pastures compared to hay and silage (21.6 and. 21.5% DM), respectively.

Based on the information presented above, lush pastures have a high feeding value and can be used as the only forage source fed to lactating dairy cows. However, more energy available in the rumen will usually be required in order to optimize microbial protein synthesis. In some cases, the addition of a RUP source and fat to the diet may have a positive effect in milk production and composition.

Herbage intake of lactating grazing cows

The amount of herbage consumed is the major determinant of herbivore production, yet is one of the most difficult aspects of forage quality to determine or predict (Buxton et al., 1996). The major regulators of intake by herbivores include physical limitations, physiological control, and psychogenic factors (Mertens, 1985).

Rates of digestion and passage of indigestible particles through the digestive tract is slow in ruminants so that the physical capacity of the digestive tract, particularly the reticulo-rumen, limits intake of certain forages (Forbes, 1993). The same author suggested that increasing speed and/or extent of digestion and the rate of passage of particles such as by grinding, increases intake. Blaxter et al. (1956) reported positive relationships between intake and digestibility. This means that plant species or parts having high digestibility are consumed to a greater extent than those with a lower digestibility (Thompson and Poppi, 1990). According to Forbes (1993), digestibility is relatively easy to measure but is probably not the most useful measure for predicting intake. This is because some feeds may be poorly digested but pass through the digestive tract relatively quickly, thereby occupying space for less time than a more digestible feed with a slower rate of passage (Forbes, 1993).

The filling effect of herbage is related to the volume of ruminal contents (Buxton et al., 1996), and to the proportion of cell wall constituents or NDF of the forage (Van Soest, 1965). Van Soest (1965) suggested that levels of NDF ranging from 55 to 60% of the DM can limit forage intake due to filling effect. Thus, the percent of cell wall content of forages has a negative correlation (-0.83) to daily dry matter intake (DMI) according to values reported by Van Soest (1971). As mentioned before in this chapter, cell wall constituent of grasses are generally greater than those of legumes. Thus, the voluntary intake is usually lower for grasses than for legumes. This was confirmed by Harris et al. (1997) when he compared intake of fresh white clover and ryegrass. Lactating dairy cows were fed *ad libitum* diets containing either 20, 50, or 80% DM of clover balanced with perennial ryegrass. Results showed that daily herbage intake of cows eating 50 and 80% clover was 11% higher than for 20% clover diets. In another study, Minson (1990f) obtained a linear relation between voluntary intake and the proportion of legumes in a mixed pasture.

In addition, Waghorn et al. (1989) studied the particle breakdown in the rumen of fresh ryegrass and alfalfa fed to cows during a restricted feeding period. Their results demonstrated that breakdown and clearance in the rumen of cows fed ryegrass was slower compared with alfalfa, indicating that intake is primarily determined by the amount and rate of breakdown of the cell wall mass in the rumen (Jones, 1981). Thus, in high quality forages, such as cool season legumes and very immature cool season grasses, the fiber content is not large enough to inhibit intake, and other factors govern.

Physiological control of intake is based on the concept that animals regulate intake to meet their energy demand (Forbes, 1993). This is unlikely to occur with high-producing lactating cows under a grazing situation. Hodgson et al. (1977) implied that under ideal grazing situations, where quantitative sward limitations are minimized, intake increases as digestibility of the forage increases, until reaching levels of OM digestibility close to the maximum for fresh herbage. Thus, herbage intake in productive grazing animals is unlikely to be affected by metabolic regulators (Hodgson et al., 1977). Furthermore, Thompson and Poppi (1990) described a study where animals were grazing either a grass or legume pasture. Animals grazing legumes had a lower amount of material in the rumen and a higher intake, yet the intakes were not sufficient for the animals to reach their genetic potential for growth. Thus, animals on legume pastures appear not to have reached a physical upper limit to distention or an upper limit to energy metabolism. In contrast, animals on grass pastures appeared to be closer to a physical upper limit (Thompson and Poppi, 1990).

Consequently, Waldo's statement (1986) which indicated that physical limits control intake of diets with low digestible energy, while metabolic needs limit intake of diets with high digestible energy density is not completely true under a grazing situation.

Thus, other factors in addition to the ones previously described can affect DMI. Psychogenic factors are important regulators of voluntary herbage intake in ruminant animals, especially high-producing dairy cows under a grazing situation. In this case herbage intake can be affected by sward characteristics, and environmental and management factors.

Sward mass, height, and uniformity are one of the most important variables that can significantly affect pasture intake by ruminants. Intake per bite is the primary animal response to variations in the physical characteristics of the sward canopy and has been shown to be positively related to green herbage mass or sward surface height (Hodgson, 1986).

Rook et al. (1994) compared herbage intake of Holstein-Friesian lactating cows fed ryegrass-white clover pastures of different compressed height (4, 6, or 8 cm). Results showed that herbage intake was highest for cows grazing pastures 8 cm height (16.8 kg/d DM) compared to 4 and 6 cm (13.9 and 15.3, respectively). Similar results were obtained in other studies (Kibon and Holmes, 1987; Fisher et al., 1995) where swards of different height were grazed by lactating cows.

Temperature and light intensity are important environmental factors that can affect herbage DMI. Data reported by the NRC (1981a) suggested that when maximum daily temperature exceeds 25^{o} C, the rate of DMI from grazing may decline rapidly due in part to the direct effects of thermal stress on the cow causing suppression of activity and the indirect decline due to the quality of the forage. Furthermore, forages grown under high temperatures have a higher stem to leaf ratio. Animals will select leaves, instead of consuming the whole plant, and therefore, bite size and rate of intake will decrease (NRC, 1981b). Also the rate of maturation rises with temperature; alfalfa grown at 17^{o} C took 52 days to reach early bloom but only 21 days at 32^{o} C (NRC, 1981b). Holden et al. (1994b) studied the total DMI and pasture DMI of lactating Holstein cows at different times during a grazing season at the Pennsylvania State University Dairy Production Research Center. Cows grazed pastures with 38% orchardgrass, 34% Kentucky bluegrass, and 18% smooth bromegrass, and were supplemented with 1 kg of concentrate DM/ 5 kg of milk, with a maximum of 10 kg and a minimum of 4 kg of concentrate DM. Average herbage mass available, and NDF content were of 2815, 2662, and 3098 kg DM/ha, and 43.1, 46.7, and 42.0% DM during spring, summer, and fall, respectively. Pasture DMI varied over time, being highest in late spring (14.5 kg/d) and autumn (15.0 kg/d) and lowest in summer (12.3 kg/d). Thus, the drop in herbage mass and cell wall content increment during summer were probably the major factors which caused the decline in intake during that period.

Light intensity is another factor that can affect forage composition and indirectly pasture DMI. At high light intensity, water soluble carbohydrates increase and cell wall carbohydrates decrease (NRC, 1981b; Van Soest, 1994b). Therefore, temperature and light intensity variations during a grazing season will indirectly affect pasture DMI by changing herbage mass, plant digestibility and NDF content.

Furthermore, stocking rate, grazing system, grazing pressure, and type and amount of supplement are important factors that can affect herbage intake. Two experiments were conducted by Le Du et al. (1979), where the effect of grazing pressure in animal performance was investigated. The different levels of herbage allowance offered to British Friesian lactating cows were of 12.2, 25.7, or 36.2 in Experiment 1 and 15.6, 50, or 70 kg/d of DM in Experiment

2. Daily herbage intake on the three different allowances in each trial were 10.7, 13.3, 14.1, and 11.5, 12.1, and 12.5 kg of OM, respectively. Results indicated that intake was depressed once the cows were forced to consume more than 50% of the herbage on offer.

Supplementary feeds are offered to grazing animals to maintain or increase total daily intakes and animal performance. They are needed because grazed herbage often fails to supply the necessary requirements (Leaver, 1986); especially in high-producing dairy cows (Polan et al., 1997).

Berzaghi et al. (1996) reported significantly lower herbage OM intakes (9.8 vs. 13.0 kg/d) for lactating dairy cows supplemented with 5.4 kg of cracked corn than for cows consuming pasture alone. Thus, substitution rate (decrease in forage intake per unit of supplement) was 0.59. However, total OM intake was similar for both treatments (Berzaghi et al., 1996). In other studies, while Leaver (1982) reported substitution rates of 0.32 to 0.46 kg of herbage DM per kg of concentrate for dairy cows milking 16 kg of milk per day, Meijs and Hoekstra (1984) reported substitution rates of 0.1 and 0.5 kg, when daily herbage allowance was of 16 or 24 kg of OM/cow, respectively. This study demonstrated that the effect of concentrate on herbage intake of grazing cows will depend on the level of daily herbage allowance. Thus, when herbage availability is low, concentrate supplementation will hardly affect herbage intake, while at high levels of herbage availability the substitution rate will be high (Meijs and Hoekstra, 1984).

Supplementation of conserved forages as a buffer feed can increase total DMI of lactating dairy cows on pasture, especially when herbage is in short supply. Phillips and Leaver (1985a) reported higher total DMI in dairy cows when free access to chopped hay was allowed for 45 minutes after the morning milking; yet herbage DMI did not differ among treatments.

Two other experiments were conducted by Phillips and Leaver (1985b), where cows were offered either pasture only, pasture plus grass silage offered for 45 minutes after the morning milking, or pasture plus overnight supplementation of grass silage *ad libitum*. The same level of herbage and concentrate was available for all treatments. In both experiments herbage DMI was depressed by offering silage, particularly when silage was offered overnight. Total DMI was increased by offering silage in experiment 2 but not in experiment 1. Phillips and Leaver suggested that reduction in herbage DMI in experiment 2 could have been due to high rainfall, lower herbage mass available confirmed by a lower compressed herbage height (7.2 vs. 9.6 cm), and a lower bite size (0.29 vs. 0.45 g DM) in cows with no silage supplementation. Thus, during periods of scarce pasture availability, supplementing cows with good quality silage will tend to increase total DMI, without a significant depression of herbage intake.

Another forage supplement for lactating dairy cows under grazing systems is corn silage. Holden et al. (1995) conducted a study to determine the effects of supplementation of high producing Holstein cows with 2.3 kg/d of corn silage DM in addition to grain (1 kg of grain DM/4 kg of milk) based on milk production at the start of the trial. Cows supplemented with corn silage had a significant lower herbage DMI than the control group (11.5 vs. 14.2 kg DM). No significant difference occurred in total DMI (22.5 and 22.7 kg DM).

In conclusion, conserved forage supplementation may improve total DMI in those cases where cows are unable or unwilling to harvest sufficient herbage during grazing. Furthermore, DMI of legume pastures is higher compared to grasses. However, sometimes environmental and management factors may prevent the use of pure legume pastures. Thus, in this situations mixed pastures should be established, and management goals should be focused in optimizing legume proportion in the sward.

Grazing Behavior in Lactating Dairy Cows

Several factors affect grazing behavior in ruminants. Cattle respond to grazing management and variations in herbage mass and structure by varying the time spent grazing, rate of biting, bite size, time spent at feeding station, and time spent selecting bites or feeding stations (Walker and Heitschmidt, 1989).

Cattle have a distinct diurnal grazing pattern, which includes a major meal beginning approximately at sunrise. Furthermore, cattle are crepuscular, meaning that they are most active at sunrise and again at sunset (Albright, 1993). Thus, nighttime grazing represents a small percentage of the total daily grazing time and contributes minimally to the daily forage intake (Stockdale and King, 1983).

In a study conducted in New Zealand with identical twins, almost 85% of the total grazing time was spent during daylight and only 15% during darkness (Albright, 1993). Furthermore, the ratio of grazing to loafing to lying down was of approximately 5:2:2 during daylight compared to 1:1:8 during darkness. Similar patterns were observed by Rook et al. (1994) also using lactating dairy cows. In this study 88% of the grazing time occurred during the 17 h of daylight, with peaks of grazing activity in mid morning and late evening. Approximately 56% of the available daylight was spent grazing with the larger meal during the evening. Rook et al. (1994) suggested that this pattern of grazing may have been an optimal foraging response to an increase of digestible nutrients in the forage at this time due to the photosynthesis process in plant leaves which occurred during the day. However, it should be noted that large evening meals have been observed in species whose food does not show such diurnal variation and other mechanisms may therefore be operating (Rook et al., 1994).

Total grazing time of cattle was reported to range between 5.8 to 10.8 h daily (Hodgson, 1986). Grazing time and biting rate increase asymptotically over a grazing season up to a maximum of 10 h daily and 66 bites per min (Phillips and Leaver 1986). In the same study, the grazing period was shorter and more intensified as the season progressed and day length was reduced, with grazing time lowest during the fall.

Allden and Whittaker (1970) observed that when forage availability was more than 3000 kg/ha of DM, grazing time was constant; but there was a twofold increase in time spent grazing when forge availability decreased to 500 kg/ha DM.

Another important factor that can affect grazing behavior is air temperature (Perera et al., 1986). Seath and Miller (1946) conducted a study in Louisiana to compare the grazing patterns of dairy cows during hot weather (30° C) versus cooler weather (22° C). During hot weather, cows grazed more at night (6.5 h) than during the day (1.9 h). Unlike previous studies described in this chapter (Rook et al., 1994; Albright, 1993), when air temperature was of 20° C, no difference was found in grazing time between day and night (4.5 and 4.7 h).

These studies demonstrate the importance of understanding grazing behavior and how cows can adapt to environmental changes and forage dynamics, in order to develop new management strategies to optimize milk production.

Rumen Fermentation Patterns

As mentioned before in this chapter, young, lush pastures are characterized by high contents of crude protein, which is rapidly degraded in the rumen. The excess dietary NPN or CP will be rapidly converted to ammonia in the rumen. Data presented by Beever (1993) revealed that of the total ammonia N (NH_3 N) produced in the rumen, only 30% was incorporated into microbial N and much of the remainder was absorbed across the rumen wall. Ammonia absorbed will be converted into urea by the liver, a conversion that costs the animal about 12 kcal/g of N (Van Soest, 1994c). Most rumen microbes depend on carbohydrates as sources of energy (Hoover and Stokes, 1991). Thus, under a grazing situation, adding fermentable carbohydrates should promote the microbial utilization of excess ammonia. Furthermore, in theory, synchronization of carbohydrate and protein degradation in the rumen should improve NH_3 N utilization. Therefore, different amounts and/or types of energy sources will have different effects in rumen fermentation patterns.

Very little information can be found in the literature about rumen fermentation patterns in lactating grazing cows. Diurnal variations of rumen pH, total VFA, and NH3 N concentrations have been barely studied. In general, rumen pH is measured and rumen fluid samples are taken only a few times after concentrate supplementation (Berzaghi et al., 1996) or a long sampling frequency is used (Jones-Endsley et al., 1997; Holden et al., 1994a; Van Vuuren et al., 1986).

Van Vuuren et al. (1986) studied the influence of level and composition of concentrate supplements on rumen fermentation patterns of six rumen cannulated Dutch-Friesian lactating cows. Cows grazed pastures based on 80 to 90% perennial ryegrass and were supplemented either with a high starch or a low starch diet (25.8 or 1.5% DM of starch) in two different amounts (7 or 1 kg/d), given in two equal portions at milking (0600 and 1600 h).

No difference was found in rumen pH between treatments, except for the 0800 h samples, which was lowest for cows supplemented with 7 kg of the high starch concentrate. The lowest pH occurred at 2400 h, after the p.m. milking, when it varied from 6.2 to 5.2.

Total VFA and NH_3 N concentrations had an inverse pattern compared to rumen pH. Maximum concentrations were at 2400 h for all treatments. Van Vuuren speculated that this could have been due to a higher pasture DMI during late afternoon and early evening, and due to the higher sugar concentrations in the herbage DM at that particular time of the day. Total VFA were not different among treatments; however, NH_3 N and iso-acid concentrations were higher on cows supplemented with 1 kg of concentrate (Table 2.5). In the same study the effects of feeding concentrates was less pronounced and therefore, amount and composition of concentrate mixtures apparently did not influence patterns of VFA concentration and pH value (Van Vuuren et al., 1986). However, with the 4 h interval, observing peaks of VFA and NH_3 N concentration could have been overlooked.

In another study, Berzaghi et al. (1996) compared rumen patterns of lactating grazing dairy Holstein cows either supplemented with 5.4 kg of corn or not supplemented. No difference was observed in rumen pH between supplemented and unsupplemented cows (Table 2.5). However, total VFA concentrations and propionate as a % of TVFA tended to be higher in cows supplemented with 5.4 kg of corn (Table 2.5), leading to a lower acetate to propionate ratio in the same treatment.

Cows grazing good quality, young, lush pastures will contain higher rumen concentrations of NH_3 N than cows fed a typical TMR diet. This is probably due to the greater concentrations of soluble protein in pastures, and frequency of feeding and greater content of NFC fed in TMR diets, which provides more α-keto acids for NH_3 fixation (Aldrich et al., 1993). However, grazing cows usually contain higher TVFA, which indicates that an extensive fermentation of fresh herbage occurs (Berzaghi et al., 1996).

Supplementation of Lactating Grazing Dairy Cows

It is evident from data obtained by Polan and Wark (1997) that generally high producing Holstein cows are not able to sustain high productions with diets based solely on pasture. Thus, it is important to determine what type of supplement will best balance nutrient requirements of cows under a grazing situation. In order to determine this, it is important first to estimate the nutrient quality of the pasture. However, this is a difficult task because of herbage quality variation and cow's selection preferences (Hoffman et al., 1993). Cows usually choose leafy material unless forced to graze closer to the ground (Polan, 1997). For example, when forage samples are cut near the ground, protein concentrations will be lower compared to samples taken at the height that cows usually graze. Thus, forage which cows actually consume is probably higher in CP than what clippings indicate (Polan, 1997). Consequently, in addition to maintaining a good quality and dense sward mass, supplementation is another important and challenging chore for maintaining an adequate dry matter and nutrient intake in high producing dairy cows.

Energy sources

The relatively high levels (1.6 Mcal/kg DM) of NE_L found in immature pastures are probably due to high digestibility and relatively high lipid content (4-6%) of pastures (Polan, 1997). However, insufficient NFC intake and increased energy requirements in grazing cows (10-20%) (Fox, 1997; Muller et al., 1995; NRC, 1989) due to increased physical activity, are the reasons why increased milk production is generally observed when energy sources are supplemented. Energy sources have to be quickly and highly degraded in the rumen to optimize N utilization by rumen microbes (Polan, 1997; Sinclair et al., 1995; Kibon and Holmes, 1987).

From studies conducted at Virginia Tech by Polan et al. (1986); Polan et al. (1996); and Polan et al. (1997) it can be concluded that levels of corn supplementation above 7 kg per day will have only modest effects on milk yield under good pasture management conditions. During the grazing seasons of 1978 and 1979, Polan et al. (1986) supplemented lactating dairy cows either with 3.6, 5.5, or 7.3 kg/d (in two equal feedings) of ground corn. Cows supplemented with 7.3 kg of corn produced slightly more milk than the other two treatments (24.8 vs. 23.4 and 23.8 kg/d). Similar results were obtained by workers at Pennsylvania State University (Hoffman et al., 1993). At Penn State corn was supplemented at the rate of 1 kg of concentrate per 4 to 5 kg of milk yield, with a maximum of 10 kg and a minimum of 4 kg (Holden et al., 1994b).

Polan et al. (1986) did not find any differences in milk fat (3.3 vs. 3.2 %) and protein (3.1 vs. 3.2 %) between cows supplemented either with 5.4 or 7.3 kg of corn, respectively. However, cows supplemented with 3.6 kg of corn had a higher milk fat content (3.5 %). In the study conducted by Hoffman et al. (1993), milk fat content was not significantly different between cows supplemented either with 1 kg of concentrate / 3 kg of milk or 1 kg of corn / 4-5 kg of milk. However, milk protein percentage (3.00 vs. 3.06 %) was lower in cows supplemented with 1 kg of concentrate / 3 kg of milk produced.

Amount of corn supplemented to grazing cows will not only depend on milk production or herbage mass, but also on sward composition. Polan, (1997); Beever and Thorp, (1996); Steg et al., (1994); Waghorn et al., (1989); Ulyatt et al., (1988); and Smith, (1973) concluded that legumes are generally a better energy source, and are more digestible than grasses. As a result, less corn supplementation may be needed when legumes are abundant for grazing to support milk production (Polan, 1997). This was confirmed by studies conducted by Harris et al. (1997) and Wilkins et al. (1994). Harris fed a mixture of fresh rye-grass and different proportions of white clover (20, 50, or 80% DM according to the treatment) *ad libitum* to lactating dairy cows. Milk yield for cows on the 50% clover diet was 18% greater than yields for cows on 20% clover. However, no significant difference was observed between 50 and 80% clover content in the diet. When the same diet was restricted to 75% of the metabolizable energy requirements, milk yield was still higher for cows fed the 50 and 80% clover diets. This means that when cows were fed *ad libitum*, the increase in milk production for cows with 50 and 80% clover in their diets was due to an increase in DMI (11%), and to an increase in the nutritive value of the diet. However, any increase in milk yield when cows were restricted could only have been due to the nutritive value of the clover, since intakes were not different (Harris et al., 1997).

In another study, Wilkins et al. (1994) compared milk yield and composition in cows grazing pastures of rye-grass and different contents of white clover (1, 15, or 20% of the total DM as clover). Cows were also supplemented either with 0, 2, or 4 kg/d of concentrate. Milk production was 2 to 3 kg/d higher for cows grazing the medium clover content pasture than cows grazing the lower clover content pasture. In contrast, differences in milk yield were only 0.07 to 0.7 kg/d for cows grazing the high vs. medium clover content pastures. No significant effect was observed in fat and lactose content between treatments. However, milk protein content was significantly lower when cows grazed the lower clover content pasture (2.84 vs. 3.02 and 2.97%). Wilkins concluded from this study that mean daily yields of milk, fat, protein, and lactose, all showed a greater response to increasing concentrate level on cows grazing swards with lower clover content compared with swards with medium and high clover content.

As previously mentioned, generally corn supplementation to grazing cows will have a negative effect in milk fat content (Polan and Wark, 1997; Hoffman et al., 1993; Polan et al., 1986). Consequently, the idea of supplementing with high-fiber concentrates instead of high-starch concentrates was suggested by Meijs (1986), and Kibon and Holmes (1987). Two studies were conducted where barley (high-starch supplement) was compared to beet-pulp (high-fiber supplement) (Fisher et al., 1996; Kibon and Holmes, 1987). No significant difference was observed in milk production between treatments. However, milk fat tended to be higher when cows were supplemented with sugar beet-pulp than when the supplement was barley. Low levels of supplementation (5 and 3 kg/d) were fed in these trials, which may explain why little differences were observed in milk fat percentage between treatments.

Protein sources

Quality pasture can be the major contributor of dietary protein. However, as previously described in this chapter, herbage CP is rapidly and highly degraded in the rumen (65-85%), and usually contains high levels of NPN. Berzaghi et al. (1996) demonstrated that when cows grazed good quality pastures, the N flow to the duodenum was mainly microbial N. This indicates that there is a vast microbial protein synthesis, and thus, it may be necessary to supply a protected AA source to provide necessary metabolizable AA for optimal milk synthesis.

During two consecutive years Polan (1997) observed differences in milk yield (25 vs. 26 vs. 28 kg/d) when cows were supplemented with corn, corn plus soybean meal, or a mix of corn, corn gluten meal (RUP source), and dried brewers grains (RUP source), respectively.

In another study, Jones-Endsley et al. (1997) compared two concentrates which contained either 5 or 16% Soyplus (RUP source). When fed in the same amount no difference was observed in milk yield. However, milk fat content was lower (2.98 vs. 3.14) and milk protein content higher (2.82 vs. 2.77) when cows were supplemented with the higher RUP concentrate.

In contrast, other studies using fish meal and corn gluten meal as RUP sources had no positive effect in milk production and composition (Polan et al., 1995). This suggests that a lack of a high rumen fermentable carbohydrate source in the diet may be the primary limiting nutrient affecting milk production in a grazing situation. Therefore, cows grazing abundant, high quality, lush pastures should be supplemented with concentrates rich in NFC, mixed with a RUP source to meet AA requirements of high producing lactating dairy cows.

Conserved forage supplementation

When grass silage is of lower or similar quality to grazed pasture, inclusion of silage in the diet generally results in a depression of milk yield relative to *ad libitum* grazed herbage. In contrast, if silage is of higher quality than pasture, its inclusion in the diet may increase milk yield (Phillips, 1988). The effects of inclusion of silage on milk fat content are varied, but tend to be inversely related to the effect on milk yield. Usually, milk fat pecentage will decrease when feeding high quality silage and will change very little or slightly increase when silage is of lower or similar quality to pasture (Phillips, 1988). In contrast, milk protein content tends to be reduced when including silage to the diet (Phillips and Leaver, 1985b).

When pasture availability is restricted, offering silage increases milk yield and fat yield, decreases milk fat content and has small variation on milk protein content (Phillips, 1988). In a study conducted with 30 Holstein cows, Holden et al. (1995) observed that the addition of 2.3 kg/d DM of corn silage to the diet did not affect milk yield or composition. However, BUN and NEFA were lower in cows supplemented with concentrate and corn silage compared to concentrate alone (27.3 vs. 29.6 mg/dl) and (204.1 vs. 233.8 μeq/L), respectively. Holden et al. concluded from this study that when ≤ 25% of the forage DM is fed as corn silage, milk production or composition may be unaffected.

In another study, Stockdale (1996) compared milk yield and composition of cows grazing either 19 or 39 kg DM of a white clover pasture supplemented with either 0 or 4.4 kg DM of corn silage. Results showed that at low pasture allowance, milk yields were 10.1 and 13.7 kg/d when 0 and 4.4 kg of DM of corn silage were fed, respectively. In contrast, no difference was observed when cows were offered the same amount of corn silage at high pasture allowance (15.5 vs. 15.9 kg/d), respectively. Furthermore, no effects of feeding corn silage on milk fat or protein content were found. However, in both high and low pasture allowances, lower NH3 N were observed when cows were supplemented with corn silage (32.1 vs. 20.6, and 33.0 vs. 22.0 mg/dl), respectively (Stockdale, 1996).

When good, abundant pastures are grazed, cows will only eat small quantities of hay (Phillips, 1988). Rearte et al. (1986) observed an increase in milk yield when cows were supplemented with concentrate plus hay. However, milk fat content did not differ between cows that were supplemented with concentrate and hay and cows supplemented only with concentrate. Yet, Phillips (1988) reported studies where milk fat percentage was partly alleviated after cow’s turnout to the pasture when supplemented with hay.

In conclusion, different types and amounts of supplements will be required under different situations. When young, lush pastures are grazed, energy in the form of NFC will be the primary nutrient required. In some cases, a RUP source, and hay may have a positive effect in milk yield and composition.

Impact of grazing on reproduction

Reproductive function can be influenced by more than simply a deficiency of certain nutrients (Staples et al., 1992). Excess intake of RDP, energy status, and age of the cow have been shown to affect reproductive performance markedly.

Recommendations for high producing dairy cows during the first 12 weeks of lactation for CP content in the diet are 17-18% of the DM with 40% of the protein as RUP (NRC, 1989). Ferguson and Chalupa (1989) calculated that rations with 30% RUP provided adequate RDP at 15% CP; but were deficient in absorbable protein (AP) even at 22% CP in the diet. Furthermore, during this period, CP above 15% containing 30% RUP supplies excess RDP. This resulted in wastage of N from the rumen and inadequate AP. This has been suggested to have negative effects on reproduction (Ferguson and Chalupa, 1989). These workers also reported that fertility was reduced in mature cows (fourth or greater lactation) consuming diets high in CP (19 vs. 16%) and diets with higher (72 vs. 62%) concentrations of RDP. However, first lactation cows increased conception rates (65 vs. 36%) when fed diets of 16% CP with high levels of RDP (Ferguson and Chalupa, 1989). But not only conception rate was observed to be affected by feeding excess RDP. Excess RDP in the rumen will be absorbed and transformed into urea mainly in the liver. This will induce an increase of urea in blood (BUN), milk (MUN), and in the reproductive tract, which may result in energy wastage and ammonia toxicity. Visek (1984) observed urea concentrations in uterine secretions to be harmful to spermatozoa.

Energy status of the cow will be another important factor affecting fertility. However, energy status per se may not be as important as when the energy balance comes to equilibrium (Butler et al., 1981). Cows in negative energy balance may be the most susceptible to reproductive problems from elevated intakes of dietary CP and RDP (Staples et al., 1992).

These considerations suggest that grazing may create reproductive problems in high producing dairy cows. However, a study conducted by Washburn and White (1997) would contradict this concept. Data of four seasonal sets of cows suggests that neither first service conception rate (51 vs. 50%) nor overall conception rate (all services) differ between confinement and pasture groups, respectively. Pregnancy rates for 75-day breeding windows were 60% for Holsteins in pasture and 56% in confinement.

Thus, it can be concluded that the management system (confinement vs. pasture) had little effect on measures of reproductive efficiency. First service conception rate, overall conception rate, percentage of cows detected in estrus and inseminated, and 75-day pregnancy rates were all similar between confinement and pasture systems (Washburn and White, 1997). However, more studies should be conducted before arriving at firm conclusions.

Milk Urea Nitrogen

Milk urea N (MUN) has a high correlation with blood urea N (BUN) (DePeters and Ferguson, 1992; Hof et al., 1997; and Baker et al., 1995), and has the potential to be used as an economical, noninvasive system to assist in monitoring the protein status of a dairy herd (Roseler et al., 1995).

Excess N supplied to the rumen or to postruminal tissues increases the concentration of BUN and MUN above baseline values and increases the excretion of urea in urine. This suggests N wastage and inefficiency of protein feeding (Baker etal., 1995). Furthermore, high endogenous concentrations of urea have been associated with impaired fertility, reduced energy availability, environmental pollution concerns and economic losses (Roseler et al., 1993). Different studies suggest different baseline values for MUN. Baker et al. (1995) obtained values for MUN of 15.1 mg/dl when fed diets balanced for CP, RDP, and RUP according to NRC. Roseler et al. (1993) and DePeters and Ferguson (1992) reported baseline values for MUN of 11.6 mg/dl and 11.3 mg/dl, respectively.

Crude protein percentage, excess N intake, and ruminal NH_3 are positively correlated with MUN (0.84, 0.77, and 0.57) (Broderick and Clayton, 1997). However, DePeters and Ferguson (1992), and Broderick and Clayton (1997) suggested that the relationship between MUN and protein:energy ratio in the diet (r= 0.96 and 0.93) is greater than MUN to each component individually. Thus, MUN usually increases as the ratio between protein and energy intake increases (Hof et al., 1997).

Baker et al. (1995) conducted a study to investigate dietary CP% and RDP effects in MUN. From this study, they concluded that MUN was sensitive to changes in CP, RDP, and RUP as excess in dietary CP% (17.5 %) resulted in higher MUN (23.3 %). Furthermore, the second highest MUN concentration (18.6 %) was observed when the diet was balanced for CP (15.1 %) but not for RDP (73 %) and RUP (27 %).

In a similar study, Roseler et al. (1993) compared 5 diets, which were designed to provide similar or different percentages of RDP and RUP relative to NRC requirements. Results from this study showed that deficient concentrations of RDP and RUP (80 and 80 % of NRC requirements) had the lowest MUN (5.6 mg/dl). When either RDP or RUP in the diets were 20% higher than

NRC (1989) requirements, MUN were higher (13.4 and 14.4 mg/dl respectively) than the balance NRC diet (11.6 mg/dl). In the diet with both RDP and RUP 20% higher than requirements, MUN (17.8 mg/dl) was greatest. Thus, values above or below 11.6 mg/dl (SE= 0.63) of MUN may indicate inefficiency in supply of RDP, RUP, or both. However, the ability to detect subtle imbalances in RDP or RUP by MUN probably is masked by the intake of dietary CP and the ratio of CP to NE_L (Roseler et al., 1993).

MUN was reported in several grazing studies conducted at Virginia Tech (Table 2.6). Similar concentrations of MUN were observed when cows were supplemented 4 kg/d DM of either coarsely ground corn or high moisture corn (17.0 vs. 16.2 mg/dl) (Polan and Wark, 1997). However, these levels of MUN were significantly lower compared to levels from grazing cows that were not supplemented (24.0 mg/dl) (Table 2.6). In another study shown in Table 2.6, cows were supplemented either with maltage, corn + fish meal, or TMR. In the latter treatment cows grazed for half a day and then were fed TMR for the next half of the day. Cows fed pasture and TMR had lower concentrations of MUN compared to cows supplemented either with maltage or corn and fish meal (12.8 vs. 16.0 and 17.8) (Table 2.6). A third study in Table 2.6 shows results of a study where cows were fed either with a control supplement (corn + soybean meal) or the same concentrate plus 3 g of Yucca shidigera per day (Polan et al., 1996). No difference was found between treatments in MUN concentration, and they were both higher than the other observations (Table 2.6).

In general, higher concentrations of MUN were observed under pasture systems (Table 2.6) compared to ideal MUN levels (11.3-15.1 mg/dl) in well balanced diets reported previously in this chapter. This suggests that usually, the high levels of RDP in pastures are not properly balanced with a readily degradable energy source in the rumen. This could be due to a deficiency of NFC or a lack of synchronization of carbohydrates and proteins in the rumen, which causes an increase in both BUN and MUN. However, more research must be conducted in this area in order to determine whether this is true.

Table 2.1. Summary of CP, soluble protein (SP), rumen degradable protein (RDP), and rumen undegradable protein (RUP) contents in pastures from several eastern States[1].

Author	Pasture type	CP	SP	RDP	RUP
		% of DM	-------------------% of CP------------------		
Holden et al., 1994a	Grass[2]	17.1	28.8	84.7	15.3
Holden et al., 1994b	Grass[2]	25.8	27.5	68.2	31.8
Holden et al., 1995	Grass[2]	30.0	49.8	88.2	11.8
Rayburn, 1994b	Grass[3]	20.0	28.0	72.0	28.0
Polan, 1997	Grass[2]	23.8			
Rayburn, 1994b	Mixed[4]	22.0	24.0	72.0	28.0
Rayburn, 1994b	Mixed[5]	22.0	30.0	72.0	28.0
Berzaghi et al., 1996	Mixed[6]	25.1			
Rayburn, 1994b	Legume[7]	24.0	31.0	72.0	28.0
Polan, 1997	Clover	26.5			

[1]Pasture samples were obtained from the States of Virginia (Polan et al., 1997; Berzaghi et al., 1996); Pennsylvania (Holden et al., 1994a; Holden et al., 1994b; Holden et al., 1995); and Maine, New York, New Hampshire, and Vermont (Rayburn, 1994).

[2]Predominantly orchardgrass with lesser amounts of bluegrass, and smooth bromegrass.

[3]Composed of 85-100% of grass.

[4]Composed of 16-50% legumes.

[5]Composed of 51-85% legumes.

[6]Predominantly grass pastures with less amounts of white clover.

[7]Composed of 86-100% legume.

Table 2.2. Amino acid profile of alfalfa, orchardgrass, and a mixed pasture.

Amino Acid	Alfalfa[1]	Orchardgrass[1]	Mixed Pasture[2]
	----------------------	% of Total AA	----------------------
Phenylalanine	6.1	6.1	5.9
Arginine	5.9	6.5	5.3
Histidine	2.6	2.5	2.3
Isoleucine	5.8	5.0	4.6
Leucine	9.4	9.1	8.7
Lysine	6.6	6.3	6.3
Methionine	1.8	2.2	1.2
Threonine	5.1	5.1	5.5
Valine	6.8	6.2	6.0

[1] Lyttleton (1973).

[2] Jones-Endsley et al. (1997).

Table 2.3. Summary of NFC, NDF, ADF, and hemicellulose (Hcel) contents in pastures from several eastern States[1].

Author	Pasture type	NFC	NDF	ADF	Hcel
		----------------------------- % of DM	----------------------		
Holden et al., 1994a	Grass[2]	30.5	49.4	26.0	23.4
Holden et al., 1994b	Grass[2]		43.9	25.6	18.3
Holden et al., 1995	Grass[2]	19.9	35.8	21.0	14.8
Rayburn, 1994b	Grass[3]	14.0	53.0	28.0	25.0
Polan, 1997	Grass[2]	14.7	49.2	25.7	23.5
Rayburn, 1994b	Mixed[4]	16.0	48.0	27.0	21.0
Rayburn, 1994b	Mixed[5]	20.0	44.0	28.0	16.0
Berzaghi et al., 1996	Mixed[6]		62.6	38.2	24.4
Rayburn, 1994b	Legume[7]	29.0	31.0	23.0	8.0
Polan, 1997	Clover	38.7	23.7	19.9	3.8

[1]Pasture samples were obtained from the States of Virginia (Polan et al., 1997; Berzaghi et al., 1996); Pennsylvania (Holden et al., 1994a; Holden et al., 1994b; Holden et al., 1995); and Maine, New York, New Hampshire, and Vermont (Rayburn, 1994b).

[2]Predominantly orchardgrass with lesser amounts of bluegrass, and smooth bromegrass.

[3]Composed of 85-100% of grass.

[4]Composed of 16-50% legumes.

[5]Composed of 51-85% legumes.

[6]Predominantly grass pastures with less amounts of white clover.

[7]Composed of 86-100% legumes.

Table 2.4. Summary of mineral contents in grass, legume, and mixed pastures.

Author	Pasture	Ca	P	Mg	K	S	Zn	Cu	Fe
		----------------		% of DM	----------------------		---------	ppm	-------
Muller et al., 1995	Grass	0.60	0.33	0.18	2.80	0.19			
Rayburn, 1994b	Grass	0.43	0.38	0.22	3.38	0.32	28	8.7	141
Fleming, 1973	OG[1]	0.46	0.25	0.21	2.00				
Powell et al., 1978	OG[1]	0.35	0.28	0.15	2.86	0.21			
NRC, 1989	OG[1]	0.58	0.54	0.31	3.58	0.21		7.0	169
NRC, 1989	BG[2]	0.50	0.44	0.18	2.27	0.17			300
Muller et al., 1995	Legume	1.20	0.33	0.42	3.00	0.22			
Rayburn, 1994b	Legume	1.21	0.33	0.30	3.07	0.26	30	9.3	430
Minson, 1990[5]	Alfalfa	1.36	0.26	0.35				5.9	
Fleming, 1973	Alfalfa	2.10	0.39	0.55	2.60				
NRC, 1989	W.Clover	1.35	0.31	0.48	2.62	0.13	17	10.0	413
NRC, 1989	R.Clover	2.26	0.38	0.51	2.49	0.20	19	9.0	164
Rayburn, 1994b	Mixed[3]	0.75	0.38	0.26	2.76	0.33	34	10.4	223
Rayburn, 1994b	Mixed[4]	0.99	0.35	0.29	2.65	0.30	29	9.4	228

[1]OG = Orchardgrass.

[2]BG = Kentucky bluegrass.

[3]Mixed pasture composed of 16-50% legumes.

[4]Mixed pasture composed of 51-85% legumes.

[5]Minson (1990c), Minson (1990d), Minson (1990e), and Minson (1990f).

Table 2.5. Summary of rumen fermentation patterns in dairy cows supplemented with different types of supplements in studies from USA and Holland.

		Supplement									
Period	Pasture Type	Type	Amount	pH	NH_3 N	TVFA	Ace	Pro	A:P	But	Author
			kg/d		mg/dl	mM	%	%		%	
Lactating	Mixed		0.0	6.4	22.4	150	63.2	18.7	3.4	12.9	Berzaghi et al. (1996)
Lactating	Mixed	Corn	5.5	6.2	17.1	148	62.4	19.1	3.3	13.5	
Dry	Grass		0.0		13.7	132	71.0	17.1	4.2	8.9	Holden et al. (1994)
Lactating	Mixed	Concentrate	6.4	5.9	19.1	103	63.5	21.2	3.0	11.9	Jones-Endsley et al. (1997)
Lactating	Mixed	Concentrate	9.6	5.8	17.6	102	62.9	22.0	2.9	11.8	
Lactating	Grass	High Starch	1.0	6.0	26.6	127			3.2		Van Vuuren et al. (1986)
Lactating	Grass	High Starch	7.0	5.9	18.2	127			2.8		
Lactating	Grass	Low Starch	7.0	5.9	16.8	130			3.2		
Lactating	Grass		0.0	6.1	18.1	122					Van Vuuren et al. (1993)
Lactating	Grass		0.0	6.4	26.7	106					
Lactating	Grass	High Starch	9.3	6.2	13.2	116					
Lactating	Grass		7.5	6.2	16.5	112					
Lactating	Grass	High Fiber	5.3	6.1	11.9	121					
Lactating	Grass		7.5	6.2	11.1	111					
Lactating	Grass	HMEC	4.5	6.3	23.2	111					

Table 2.6. Means of MUN from three trials conducted at Virginia Tech with dairy grazing[1] cows fed different supplements.

	Supplement[2]							
Author	CGC	HMC	NS	MALT	C+F	TMR[3]	C+D	C
	----4 kg/d DM----			-----5.6 kg/d DM----			----5.0 kg/d DM----	
Polan and Wark (1997)	17.0[a]	16.2[a]	24.0[b]					
Polan et al. (1997)				16.0[a]	17.8[a]	12.8[b]		
Polan et al. (1996)							24.9[a]	23.9[a]

[1]Cows grazed mixed pastures of predominantly orchardgrass, with lesser amounts of Kentucky bluegrass and white clover.

[2]CGC = coarsely ground corn (4.0 kg/d DM), HMC = high moisture corn; NS = No supplement; MALT = maltage with 47% pressed brewers grain, 28% coarsely ground corn, and lesser amounts of soyhulls, cotton seed meal, brewers yeast and premix; C+F = 84.8% corn, 11.4 fishmeal, and 3.8 mineral; C+D = ground-corn + soybean meal + 3 g of Yucca shidigera; C = ground-corn + soybean meal.

[3]Treatment in confinement fed only a TMR diet which included 28.5% corn silage, 29.1% alfalfa haylage, 26.0 high moisture corn, 8.5 soybean meal, 5.8 whole cotton seed, and 2.1% mineral-vitamin premix.

[ab]Means with different superscripts within rows differ ($P < 0.05$).

CHAPTER 3

MILK PRODUCTION AND COMPOSITION, RUMEN FERMENTATION PARAMETERS, AND GRAZING BEHAVIOR OF DAIRY COWS SUPPLEMENTED DIFFERENT FORMS AND AMOUNTS OF CORN

(ABSTRACT)

Three experiments were conducted during the grazing season of 1997. The objectives were to compare milk production and composition, body weight change and body condition score, and to determine time patterns of grazing between cows supplemented with different forms and amounts of corn. Also rumen fermentation parameters were measured in cows supplemented with two different forms of corn. In Experiment 1, 36 Holstein cows were supplemented either with 6, 6, 6, or 4 kg/d DM of high moisture corn, coarsely ground corn, finely ground corn, or high moisture corn in two equal feedings, respectively. Milk yield was similar (30.8, 30.1, 29.7, and 30.5 kg/d) among treatments. Milk protein (2.96, 2.96, 2.99, and 2.95%) and MUN (13.7, 14.3, 15.0, and 15.8 mg/dl) did not differ among treatments. Body weight change and body condition score change were similar among treatments (23.1 and -0.24). During Experiment 2, four rumen cannulated cows in mid-lactation were supplemented twice daily with 6 kg/d DM of either coarsely ground corn or high moisture corn in two equal feedings after each milking. After the p.m. milking, ruminal pH was measured and rumen fluid samples were collected to determine ammonia N and VFA. While grazing, this was repeated at 0.5, 1, 2, 3, …8 h post-corn feeding (0 h). Ruminal pH was similar for both corn supplements and was lowest (5.9 and 5.8) at 5 and 8 h, respectively. Rumen ammonia N concentrations started to increase approximately 2 h after cows began grazing, reaching maximum concentrations 5 h later. In Experiment 3, the number of cows grazing, lying, or standing was recorded every half hour, for

two consecutive days, while grazing. Cows grazed an average of 6.4 h/d, 4.1 h in the afternoon and 2.3 h in the morning. Similarity in milk production, milk composition, BW change, and BCS between treatments indicates that the quality and availability of pasture permitted equal response regardless of the type or amount of corn supplemented.

INTRODUCTION

High quality pastures are usually characterized by high levels of crude protein, which is highly degradable in the rumen (Nungent and Mangan, 1981; Van Vuuren et al., 1991). Rumen degradable protein ranged from 68 to 88% of CP in grazing studies conducted by Minson (1990b), Holden et al. (1994a), Holden et al. (1994b), Rayburn (1994b), and Berzaghi et al. (1996). As a result, a large proportion of herbage protein is rapidly transformed into ammonia by rumen microbes, which results in high concentrations of ammonia N (NH_3 N) being absorbed across the rumen wall, and converted primarily in the liver to urea. Thus, when high quality pastures, and especially predominantly grass pastures are grazed, the ratio of available N to energy is often higher than the optimum suggested by Hoover and Stokes (1991). Hoover and Stokes (1991) also suggested that most rumen microbes depend on carbohydrates as sources of energy. Thus a source of non-fiber carbohydrate (NFC) should be supplemented to high producing grazing cows in order to maximize NH_3 N utilization by rumen microbes. Extensive research conducted at Virginia Tech and Pennsylvania State University suggest that supplementing more than 8 kg/d of dry corn has little or no effect on cow performance when enough herbage is available (Polan et al., 1986; Hoffman et al., 1993; Holden et al., 1994b; Polan, 1997).

Furthermore, in order to optimize microbial growth, several studies would suggest that the carbohydrate source supplemented should have a similar rate and extent of degradation in the rumen compared to that of herbage CP (Sinclair et al., 1995; Herrera-Saldana et al., 1990; Van Vuuren et al., 1990; Siddons et al., 1985). However, this has not been investigated in high producing cows under a grazing situation, where concentrate is supplemented only twice a day.

Typically, grazing cows in the US are supplemented with concentrates based on dry corn. However, this type of corn, unless finely ground, is not as highly degraded in the rumen as high moisture corn (HMC) (Nocek and Tamminga, 1991). Disruption of the protein matrix of the endosperm and the gelatinization of the starch of the grain are important for improving digestion of corn (Hale, 1973; French, 1973; Theurer, 1986). In several studies where beef or dairy cattle in confinement were fed different forms of corn, a higher rate and extent of ruminal degradation in HMC was observed compared to dry corn (Nocek, 1987; Galyean et al., 1981; Galyean et al., 1976). Furthermore, the same authors observed that grinding increased the extent of degradation for all forms of corn.

Limited data are available on how different forms of corn supplements (Polan and Wark, 1997) and different amounts of HMC affect milk production and composition of lactating grazing cows. Therefore, Experiment 1 was conducted to measure and compare milk yield, composition, milk urea N (MUN), BW change, and body condition score (BCS) change between Holstein cows supplemented with different forms of corn and two different amounts of HMC. Furthermore, the objectives of Experiment 2 were to measure and compare rumen pH, VFA, and NH_3 N concentrations in cows supplemented with 6 kg/d DM of either coarsely ground corn (CGC) or HMC.

There are several environmental, nutritional, and management factors that can affect the grazing behavior of lactating cows. Nighttime grazing represents a very small proportion of the total grazing time (Stockdale and King, 1983). This was confirmed by a study conducted by Rook et al. (1994), where 88% of the total grazing time occurred during daylight. Typically, two grazing peaks have been observed in lactating dairy cows: one in the morning and another in the afternoon (Rook et al., 1994; Albright, 1993). However, duration of these grazing peaks and comparison of grazing patterns during the afternoon and the morning has been rarely studied (Rook and Huckle, 1995). Thus, during Experiment 3, the time patterns of grazing in lactating cows at the Virginia Tech Dairy Complex were observed, to compare the time spent grazing during the morning and afternoon, and during daylight and nighttime. Also grazing patterns were compared between high and low milk producing Holstein cows.

MATERIALS AND METHODS

Grazing and feeding management

Four fields (approximately 2.7 ha each) of a mixed pasture composed of primarily orchardgrass (*Dactylis glomerata*) with lesser amounts of Kentucky bluegrass (*Poa pratensis*) and white clover (*Trifolium repens*) were used in an intensive rotational manner. A new area was available daily after the p.m. milking by moving an electrified nylon string across the field. When pastures were not adequately grazed, stubble was either clipped or grazed by dry cows. Water was available at all times in the field and when cows were in the lot prior to milking. During the second week of June, pastures were fertilized with 67 kg/ha of N and 23 kg/ha of potash.

Corn was supplemented twice a day, after each milking. Cows were in the field for 7 h (1500-2200 h) after the p.m. milking, and for 6 h (0400-1000 h) after the a.m. milking. At 2200 and 1000 h they were brought into a dirt lot where orchardgrass hay and a mineral-vitamin premix (Table 3.1) were offered prior to milking.

Sward measurements and analysis

A minimum of 20 compressed sward heights (CSH) were assessed twice per week using a disk meter. The disk meter consisted of an acrylic disk, similar to the one described by Rayburn (1994a) and Murphy et al. (1995). The disk, which weighed 700 g, had a diameter of 50.3 cm and a hole in the center designed to fit and slide up and down a steel rod. This rod was held in a vertical position with its base at ground level, and the disk was dropped from a constant distance (1.5 m) to settle on the sward. The disk was allowed to rest on the sward, and the distance between the ground and the disk was measured to determine the CSH. Measurements were done every 10 paces by tracing two diagonal transects across the area available prior to grazing

Pasture mass (kg/ha DM) was estimated by using the cutting technique described by Frame (1981). Twice per week, a minimum of 4 samples were collected by tracing a diagonal transect across the area available prior to grazing, and clipping a quadrant (0.25 m^2 each) every 20 paces. Electric shears were used to cut the samples, leaving a stubble of approximately 5 cm. To ensure there was no difference between operators, pasture samples were cut and CSH was assessed by only one person. Immediately after collection, pasture samples were weighed and oven-dried at 55^{o} C for 48 h or until constant weight. Herbage DM yield (HDMY) (kg/ha DM) was calculated using the average DM weight of the samples ($\overline{W}_2$) by using the following equation:

$$\text{HDMY (kg/ha DM)} = \frac{\overline{W}_2 \text{ (kg) x } 10{,}000 \text{ m}^2\text{/ha}}{0.25 \text{ m}^2}$$

Pasture samples were later ground to pass a 1-mm sieve of a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and composited according to field (F1, F2, F3, F4) and month (May, June, and July). The average pasture composition was calculated for each month of the study. Samples were analyzed for DM, ash (AOAC, 1990), CP (AOAC, 1990), ADF (Goering and Van Soest, 1970), NDF (Van Soest et al., 1991), and macro and micro minerals (AOAC, 1990) by the Cumberland Valley Analytical Services Laboratory (Maugansville, MD). Hemicellulose (Hcel), NE_L, and non-fiber carbohydrates (NFC) were calculated using the following equations:

Hcel (%) = NDF - ADF

NE_L (Mcal/kg DM) = 1.0876 - 0.0127 x ADF (Undersander et al., 1993)

NFC (%) = 100 - (CP + NDF + Ash + EE) (Mertens, 1992)

The Pennsylvania State University equation for grasses was used for NE_L determination.

Experiment 1

Cows and experimental design. Twenty four primiparous and twelve multiparous Holstein cows averaging 107 DIM initially were used during a 10 week study beginning on May 13. Cows were supplemented either with 6, 6, 6, or 4 kg/d DM of high moisture corn (HMCH), coarsely ground corn (CGC), finely ground corn (FGC), or high moisture corn (HMCL), respectively, in two equal feedings. Corn refusals, if any, were weighed after feeding time. The experimental design was a restricted randomized complete block design, where cows were blocked according to parity, and then stratified according to milk production and DIM, after which they were randomly allotted to four groups.

Cows were allowed a grazing adaptation period of 10 d prior to beginning experimental diets. During this period cows were fed a TMR diet during half of the day and grazed a predominantly grass pasture during the other half of the day. Initially (week 0) milk production, BW, and body condition score (BCS) averaged 36.4 kg/d, 510 kg, and 2.88, respectively (Table 3.2).

Sample collection and analysis. Milk production was electronically recorded at each milking. Milk was sampled from each milking every two wk, starting on week 0. Individual a.m. and p.m. samples were analyzed for fat, protein, and SNF at the Blue Ridge DHIA Laboratory (Blacksburg, VA), by using infrared spectrometry (Multispec Mark I®; Foss Food Technology, Eden Plains, MN).

Additional milk samples were collected from each milking at 2, 6, and 10 wk of the study. Individual a.m. and p.m. samples were analyzed to determine MUN concentrations, using the urease method described by Weatherburn (1967).

The BW and BCS were determined at 0, 5, and 10 wk. Cows were weighed at noon, prior to the p.m. milking. Body condition score was obtained by four independent evaluators, using the scoring system based on a five-point scale (1 = very thin to 5 = very fat) (Wildman et al., 1982). The BW change and BCS change were calculated from the difference between week 0 and week 10 (Total Period), week 0 and week 5 (Period 1), and between week 5 and week 10 (Period 2).

Corn was ground in a hammer mill at 270 RPM using a 9.7-mm screen to obtain the coarsely ground corn (CGC). The finely ground corn (FGC) was obtained by grinding at 540 RPM using a 4.8-mm screen, and HMC was rolled with a gap setting of 0.79 mm using corrugated rollers. The different types of corn were sampled at 1, 5, and 10 wk of the study. Later, samples were ground to pass a 1-mm sieve using a Cyclotec mill (Tecator 1093, Hoganas, Sweden), and composites of these samples were obtained.

Composites of the different forms of corn were analyzed for N content by Kjeldahl method (AOAC, 1990), and the N content was multiplied by a constant factor of 6.25 to estimate CP. The ADF (Goering and Van Soest, 1970), and NDF (Van Soest et al., 1991) were also determined. Hemicellulose and NFC concentrations were calculated with the same equations used for pasture analysis. The NE_L, ash, EE, and macro and micro minerals were obtained from NRC (1989) tables.

Estimation of DMI. Dry matter intake was calculated using the equation of Rayburn and Fox (1993):

DMI (kg/d) = 0.023 x BW (kg) + 0.0201 x DIM + 0.286 x 4%FCM (kg/d) - 0.0979 x NDF (%)

In this equation, DMI was correlated with BW, DIM, FCM, and NDF (R^2 = 0.99; SD = 1.66; CV = 0.08). Furthermore, the prediction error for this regression model was only 1.4 kg/d of DM.

Statistical analysis. Data were analyzed by analysis of covariance, using repeated measures, and the General Linear Models Procedure of SAS. The model used in the experiment was:

$$Y_{ijklm} = \mu + T_i + P_j + COV_k + (T \times P)_{ij} + C\,(T \times P)_{(ij)\,l} + W_m + (W \times T)_{mi} + (W \times COV)_{mk} + (W \times P)_{mj} + (W \times T \times P)_{mij} + E_{ijklm}$$

where

Y_{ijklm} = dependent variable,

μ = overall population mean,

T_i = effect of treatment i (i = HMCH, CGC, FGC, or HMCL),

P_j = effect of block (parity)j (j = primiparous or multiparous),

COV_k = covariate adjustment for pretreatment performance,

$(T \times P)_{ij}$ = effect of interaction between treatment i and parity j,

$C\,(T \times P)_{(ij)\,l}$ = effect of cow l within treatment i and parity j,

W_m = effect of week m (m = week 1, 2, 3, …, 10),

$(W \times T)_{mi}$ = effect of interaction between week m and treatment i,

$(W \times COV)_{mk}$ = effect of interaction between week m and covariate k,

$(W \times P)_{mj}$ = effect of interaction between week m and parity j,

$(W \times T \times P)_{mij}$ = effect of interaction between week m, treatment i and parity j, and

E_{ijklm} = residual error term.

This same statistical model was used to analyze and compare MUN concentrations between treatments; however, the covariate was not included, as no preliminary data were obtained for MUN.

Experiment 2

Cows and management. Four ruminal cannulated cows in mid-lactation, 1 Holstein and 1 Jersey each, were supplemented with 6 kg/d DM of either HMC or CGC, in two equal feedings. Cows were individually supplemented, and weigh-backs, if any were recorded. Cows were allowed an adaptation period of 17 days prior to the beginning of the trial.

Sample collection and analysis. First ruminal samples were collected and rumen pH was measured at 1345 h, 15 min before corn feeding. Sampling and pH measurements were repeated at 0.5, 1, 2, 3, 4, 5, 6, 7, and 8 h after corn supplementation, between 1430 and 2200 h. Ruminal pH was measured in two areas of the rumen (anterior and dorsal) using a portable pH meter (model 2000, VWR Scientific, Bridgeport, NJ). Ruminal samples were collected from the anterior and dorsal region of the rumen. After removal of the samples, these were immediately strained through six layers of cheese cloth, and rumen fluid was composited. Approximately 150 ml of composited rumen fluid was collected each time.

Aliquots (5 ml) of rumen fluid were preserved with either 1 ml of 20% para-phosphoric acid or 1 ml of internal standard (7 μmol/ml of isocaproic acid) for NH_3 N determination or for VFA analysis, respectively. These subsamples were then stored at -20 ^{o}C until analyzed.

Ruminal fluid was centrifuged at 5000 x g for 10 min to remove particulate matter and then filtered through a 0.45-μm Metricel filter (Gelman Sciences, Inc., Ann Arbor, MI).

Ruminal VFA was determined on the supernatant of rumen fluid by gas chromatography. Rumen samples (0.5 μl) were injected into a chromatograph (Varian Vista 6000, Varian Vista, Palo Alto, CA), with a glass column packed with 10% SP-1200, 1% H_3PO_4 liquid phase on

80/100 Chromabsorb W AW packing (Supelco Inc., Bellefonte, PA). The column temperature was 125 ^{o}C. Nitrogen was used as a carrier with a flow of 80 ml/min and hydrogen and air were used as detector gases with flows of 40 and 60 ml/min, respectively.

Rumen NH3 N was determined on the supernatant of rumen fluid according to the procedure described by Weatherburn (1967), using a spectrophotometer (Spectronic 1001, Bausch & Lomb, Rochester, NY).

Statistical analysis. Data were analyzed using the General Linear Models Procedure of SAS (1982). Least squares means (LSM) and pooled standard error of the means (SEM) were obtained. The model used for the experiment was:

$$Y_{ijk} = \mu + TRT_i + COW(TRT)_{(i)\,j} + TIME_k + (TRT \times TIME)_{ik} + E_{ijk}$$

where

Y_{ijk} =	dependent variable,
μ =	overall population mean,
TRT_i =	effect of treatment i (i = HMC or CGC),
COW (TRT) $_{(i)\,j}$ =	effect of cow j in treatment i (j = 1, 2),
$TIME_k$ =	effect of time (h) of sampling k (k = -0, 0.5, 1, 2, 3, …, 8),
(TRT x TIME)$_{ik}$ =	effect of interaction between treatment i and time of sampling k, and
E_{ijk} =	residual error term.

Significance and SE of the treatment effect was tested by using the cow within treatment effect as the error term.

Experiment 3

Cows and experimental design. Cows used in Experiment 1 and 2 (38 Holstein and 2 Jersey) were observed for two consecutive days during grazing time.

Cows were supplemented with either 7.8, 6.7, 6.7, or 5.2 kg/d of high moisture corn (HMCH), coarsely ground corn (CGC), finely ground corn (FGC), or high moisture corn (HMCL), respectively, in two equal feedings after milking.

Grazing behavior of the 40 cows was observed as a group. The number of cows grazing, lying, or standing was recorded every half hour. Individual behavior was recorded for the four Holstein cows each with the most (33 kg/d) and least (21 kg/d) daily milk yield.

Cows were allowed to graze a new area of approximately 0.6 ha daily starting after the p.m. milking. Average CSH and HDMY were of 13.8 cm and 1450 kg/ha, respectively. Stocking density was 66.7 cows/ha.

Sunrise and sunset occurred at 0620 and 2036 h, respectively, with 14 h of daylight during both days of the experiment. Maximum and minimum air temperatures averaged 27.5 and 20.5^{o} C, respectively.

Statistical analysis. Data obtained from the individual grazing behavior of the 8 Holstein cows were analyzed using the General Linear Models Procedure of SAS (1982). Least squares means and SEM were obtained. The model used in the experiment was:

$$Y_{ijk} = \mu + PROD_i + COW(PROD)_{(i)\,j} + TIME_k + (PROD \times TIME)_{ik} + E_{ijk}$$

where

Y_{ijk} =	dependent variable,
μ =	overall population mean,
$PROD_i$ =	effect of milk production i (i = high (33 kg/d) or low (21 kg/d)),
$COW(PROD)_{(i)\,j}$ =	effect of cow j in production group i (j = 1, 2, 3, and 4),
$TIME_k$ =	effect of grazing time k (k = morning grazing or afternoon grazing),
$(PROD \times TIME)_{ik}$ =	effect of the interaction between milk production i and grazing time k,
and	
E_{ijk} =	residual error term.

Significance and SE of the treatment effect was determined by using the effect of cow within treatment as the error term.

RESULTS AND DISCUSSION

Experiment 1

Pasture and corn composition. Average pasture composition is reported for each month of the experiment (Table 3.3). Pastures contained high levels of CP throughout the experiment, with maximum concentrations during the month of June. Nitrogen was applied at the beginning of that month. Highest NDF and ADF contents (56.1 and 27.8% of DM) were observed during July, which was expected, as warm and dry weather are characteristic during that time of the year. The high proportions of hemicellulose (Hcel) reflected the predominance of grass species in the fields, predominantly orchardgrass. Relatively high energy values were calculated in pastures during May and June (1.68 Mcal/kg DM of NE_L), but NE_L dropped to 1.62 Mcal/kg of DM during the month of July. The higher CP percentage of pastures during June, and the higher CP and NDF percentage of pastures during July resulted in lower calculated NFC (6.6 and 4.3%), compared to NFC during the month of May (14.6%).

Mineral concentrations were within normal ranges for high quality, predominantly grass pastures (Muller et al., 1995; Rayburn, 1994b; and Powell et al., 1978). Magnesium was always above 0.2% DM, however, potassium was high, averaging 3.7, 4.2, and 4.6% of DM during May, June, and July, respectively. While the percentage of potassium in the pasture exceeded that recommended by NRC (1989), magnesium concentration was always lower than the minimum 0.30% recommended by Grumes (1983) for lactating grazing cattle. This high concentrations of potassium may interfere with magnesium metabolism and utilization, and is considered to be a factor in hypomagnesemia in grazing cows (Ward, 1966; and NRC, 1989). Although no signs of hypomagnesemia were observed during the experiment, subclinical symptoms like a decrease in milk production may have occurred. When cows were fed a TMR diet, O'Connor et al. (1988) and Teh et al. (1985) observed that milk production increased 5.2 and 9%, respectively when dietary Mg was increased from 0.26 to 0.48 and 0.22 to 0.45% DM, respectively.

Nutrient composition of the different types of corn supplemented is shown in Table 3.4. Energy levels were highest for HMC, and lowest for CGC, according to NRC (1989).

Forage availability. Compressed sward height averaged 17.3, 13.7, and 15.6 cm for predominantly grass pastures during the months of May, June, and July, respectively. When CSH was tested against known herbage DM yields (kg/ha of DM) the following regression equation was obtained:

HDMY = -295.38 + 122.39 x CSH

The SE for the intercept and slope were 363.1 and 23.3, respectively. As shown in Figure 3.1, a relatively strong correlation between HDMY and CSH was obtained ($r = 0.73$). Previous studies showed correlations ranging from 0.39 to 0.62 (Castle, 1976) and from 0.70 to 0.94 in tall fescue pastures (Bransby et al., 1977; and Vartha and Matches, 1977). Furthermore, a correlation of 0.88 was reported for grass-legume pastures by Rayburn (1994a).

Average HDMY (kg/ha of DM) for each week of the trial is shown in Figure 3.2. Relatively high HDMY were observed during the second half of May until the beginning of June (wk 5 of the study), with the highest HDMY observed during week 4. The lowest HDMY was also observed during the month of June (wk 6), when it decreased to 739 kg/ha DM. After week 6, HDMY increased to 1300 kg/ha of DM and remained constant until the end of the experiment. Furthermore, HDMA (kg/day per cow of DM) was calculated based on HDMY, the area allowed for grazing per day, and the number of cows grazing. This followed similar patterns of HDMY, being highest during the first 4 weeks (30 kg/d DM per cow), and lowest during week 6 (8.2 kg/d DM per cow) (Figure 3.3).

This drop in HDMY after week 4 was due to unusual low temperatures during the spring and dry weather during the summer, which affected pasture regrowth (Table 3.5). This is why

6.8 kg/d DM of alfalfa silage were added to the diet during weeks 5 and 6 of the experiment, to balance the decreased pasture available in the field. At the beginning of week 7 alfalfa silage was replaced by allowing the cows to graze for 3 h every morning an alfalfa-orchardgrass pasture. The HDMY of the alfalfa-orchardgrass pasture averaged 1651 and 1277 kg/ha DM during week 7 (June) and weeks 8, 9, and 10 (July), respectively. Cows were allowed to graze an area of 0.15 to 0.21 ha every morning, and HDMA averaged 6.9 kg/d DM per cow from week 7 until the end of the experiment of the alfalfa-orchardgrass pasture. Table 3.6 shows the chemical composition of the alfalfa-orchardgrass pasture, alfalfa silage, and orchardgrass hay used during the experiment.

Stocking rate was 3.0 cows/ha during week 1 until the end of week 6. As a new field of an alfalfa-orchardgrass pasture was included into the rotation at the beginning of week 7, stocking rate decreased to 2.4 cows/ha.

Milk production and composition. Mean milk yield per week is shown in Figure 3.4. Milk production curves followed similar trends compared to those from other studies that used cows in a similar stage of lactation (Polan, 1997; Holden et al., 1995; and Hoffman et al., 1993). Milk production declined rapidly during the first 4 wk of the experiment in all treatments. It then reached a plateau, remaining relatively constant until the end of the experiment. Least squares means of milk production and composition are shown in Table 3.7. No significant differences were observed among treatments. However, cows supplemented with HMCH produced more milk during weeks 1, 3, and 4 of the experiment (Figure 3.4). Similarly, Polan and Wark (1997) did not find differences in milk yield between grazing cows supplemented with 4 kg/d DM of either HMC or CGC. These observations agree with data reported in other studies where no difference in milk production occurred when cows were fed a TMR diet containing 42.4% of either ground dry corn or rolled HMC (Wilkerson et al., 1997). Furthermore, a lack of differences in milk yield was also reported when cows in confinement were fed concentrates based on HMC compared to dry shelled corn (Clark et al., 1973; Jones, 1972; McCaffree and Merrill, 1967). In contrast, cows fed a TMR diet containing 42.4% of HMC tended ($P \leq 0.1$) to produce more milk compared to cows fed the same TMR diet containing the same proportion of dry corn (Wilkerson et al., 1997). In the same study, Wilkerson and co-workers reported 2.2 kg/d more milk in cows fed diets containing ground corn (6.4 - mm screen) compared to rolled corn (gap setting of 0.58 mm).

A treatment by week interaction ($P \leq 0.05$) occurred for milk production and FCM, as difference in milk yield among treatments varied during the study (Figure 3.4). Milk fat, protein, and SNF percentage and yield did not differ among treatments ($P > 0.05$). This agrees with results reported by Polan and Wark (1997), who did not find differences in milk fat (4.68 vs. 4.08%) or protein percentage (3.52 vs. 3.61%) when grazing cows were supplemented 4 kg/d DM of either CGC or HMC. In their study, Holstein and Jersey cows were used, which may be the reason for the higher milk fat and protein percentages. Similar responses in milk composition were observed in other studies where cows were in confinement (Clark et al., 1973; Jones, 1972). In contrast, McCaffree and Merrill (1967) observed that milk fat percentage decreased when cows were fed corn and grass silages containing rolled HMC compared to ground dry shelled corn (3.02 vs. 3.56%). Milk fat percentage and yield did not differ in cows fed a TMR diet containing either rolled HMC, ground HMC, rolled dry corn, or ground dry corn (Wilkerson et al., 1997). However, in the same study, Wilkerson and co-workers reported higher ($P \leq 0.05$) milk protein and SNF percentages for cows fed diets containing ground compared to rolled corn. In the same study, milk protein yield was greater ($P \leq 0.05$) for cows fed HMC compared to dry corn.

The MUN concentrations differed during the experiment, being highest during week 6 of the study (18 mg/dl) (Figure 3.5), which may have occurred due to higher CP in the pasture because of N fertilization during week 5 of the trial. However, no significant difference was observed in MUN concentration among treatments (13.7, 15.0, 14.3, and 15.8 mg/dl) (Table 3.7). Only one study has been conducted comparing MUN concentrations in grazing dairy cows supplemented with HMC vs. CGC (Polan and Wark, 1997). No significant difference was found between treatments (17.0 vs. 16.2 mg/dl) in that study, supporting the observations reported in the present trial.

These results suggest that NH_3 N utilization by rumen microbes was not improved when cows were supplemented with a more digestible carbohydrate source (HMC vs. FGC vs. CGC), nor when more HMC was included in the diet (6 vs. 4 kg/d DM). However, MUN concentrations observed in this experiment were slightly lower compared to MUN concentrations observed in grazing cows (Polan et al., 1993; and Polan et al., 1996; Polan and Wark, 1997). Furthermore, MUN were not extremely high compared to recommended baseline values reported in previous studies for cows in confinement. Roseler et al. (1993), and DePeters and Ferguson (1992) reported values for MUN of 11.6 and 11.3 mg/dl when cows were fed TMR diets balanced for CP, RDP, and RUP according to NRC (1989). In contrast, Baker et al. (1995) obtained baseline values for MUN of 15.1 mg/dl when the diet was balanced for CP, RDP, and RUP according to NRC (1989) recommendations.

Body weight and condition score change. There were no significant effects of type of supplement on mean BW change or BCS change (Table 3.8). The same table shows that cows supplemented with HMCL increased BW slower ($P \leq 0.01$) compared to the other treatments. Theurer (1986) reported reviewed data where beef cattle fed either dry rolled or HMC did not differ in daily BW gain (1.2 vs. 1.3 kg/d). In addition, Hale (1973) reported no significant advantage of ground corn over rolled or crushed corn for beef cattle in a feed-lot system. However, a better feed conversion was observed in steers fed HMC compared to dry-rolled corn. Similar responses were reviewed by Jones et al. (1974).

The BCS declined during Period 1 (week 0 to week 5) for all treatments, but increased during Period 2 (week 5 to week 10) for HMCH, FGC, and CGC treatments, and remained constant for cows on HMCL treatment (Table 3.8). During the study, BCS decreased 0.20, 0.15, 0.25, and 0.35 units for cows in the HMCH, FGC, CGC, and HMCL treatments, respectively; however, mean BCS was never below 2.5. While similar responses were observed in BW change and BCS by Hoffman et al. (1993), other workers found an overall depression in BW of 55 kg, and 0.5 units of body condition in grazing cows supplemented with similar amounts of concentrate (Jones-Endsley et al.,1997). Differences in BW change between these studies and the present one may have been due to the fact that 67% of the cows used in this trial were primiparous cows, which were still growing.

Estimation of DMI. Dry matter intake was estimated for the different treatments during weeks 1, 5, and 10 (Table 3.9). Corn and orchardgrass hay intake were estimated from the feed refusals obtained during the study. Thus, pasture intake was calculated from the difference between total DMI and corn plus hay daily intake. During weeks 5 and 6, alfalfa silage was also subtracted from the total DMI in order to estimate pasture intake. Total DMI was numerically higher in week 1 of the study, and decreased in weeks 5 and 10 (Table 3.9). Pasture intake during weeks 1 and 10 were similar to those reported in other studies using cows with similar DIM, and milk production and composition (Berzaghi et al., 1996; Holden et al., 1994b). Grain supplementation was slightly higher (7.2 to 7.6 kg/d DM) in the study of Holden et al. compared to the present study. Total DMI was approximately 2 to 4 kg/d higher in their study. A similar trend of pasture DMI decrease as the season progressed was observed by Holden and co-workers, as average pasture intake was highest during the month of May (15.1 kg/d DM), and lowest in July (11.6 kg/d DM).

The low pasture DMI reported here and elsewhere, combined with the decrease in milk yield observed in the first weeks of this experiment may suggest that high producing cows may cease grazing before consuming the amount of nutrients required for maintaining milk yield. Voluntary intake in grazing cows can be regulated not only by metabolic and physical restrictions, but also by ingestive behavioral restrictions (Forbes, 1988; Kolver and Muller, 1998). This is supported by the results reported in a study conducted by Chilibroste et al. (1997), where time spent grazing, bite rate, bite mass, and intake rate were measured during the morning in lactating dairy cows grazing a predominantly perennial ryegrass pasture. Rumen DM content was weighed before and after grazing to determine intake rate. Results from this study showed that cows took large bites (> 0.9 g/bite) at a fast rate (> 61 bites/min), resulting in a high rate of intake (> 0.61 kg/100 kg BW per h) during the first hour of grazing. However, as grazing time was extended to 1.75 h, bite mass and bite rate significantly decreased, which resulted in a decline in rate of intake (0.43 kg/100 kg BW per h). Additional increases in available grazing time to 2.5 and 3.25 h resulted in little further decline. Based on these results and the weight of rumen DM content observed in their study, Chilibroste and co-workers concluded that cows stopped grazing or interrupted the first meal before their ruminal capacity was reached. Furthermore, results from a study conducted by Kolver and Muller (1998) agree that the decrease in DMI may be the primary factor depressing milk production when cows are grazing high quality pasture compared to a TMR diet fed in confinement.

Experiment 2

Rumen fermentation patterns. Ruminal fermentation parameters are reported in Table 3.10. No significant difference was observed in rumen pH (6.0 vs. 6.1) between cows supplemented with 6 kg/d DM of either HMC or CGC. The lowest pH (5.8 and 5.9) were observed at 8 h after corn supplementation, for HMC and CGC, respectively (Figure 3.6). Similarly, Van Vuuren et al. (1986) found the lowest rumen pH 8 h after lactating grazing cows were supplemented with a high or low starch concentrate. This suggests that the lowest ruminal pH may have occurred due to fiber fermentation rather than starch fermentation after corn feeding. Similar conclusions were suggested by Aldrich et al. (1993) when he fed a diet high in RDP (65.5%) to cows on a dry-lot system. Thus, a small proportion (20 to 30%) of corn in the diet, will normally cause little or no depression in digestibility of forages (Ørskov, 1986). Hoover (1986) suggested that reductions in ruminal pH to a 5.8 to 6.2 range, that are cyclic and of short duration, will cause a moderate, temporary depression in fiber digestion. Thus, only a small decrease in the rate of fiber digestion may have occurred in the present study due to pH depression.

Acidity was greater as VFA concentrations increased. Total VFA tended to increase, reaching maximum levels (140 and 131 mM) in cows supplemented with HMC and CGC, respectively, approximately 7 h after grazing began (Figure 3.7). This confirmed that maximum rumen fermentation activity may have occurred at this time due to plant fiber digestion. Similar responses were observed by Van Vuuren et al. (1993) and Van Vuuren et al. (1986). However, average total VFA reported in his studies and in others (Holden et al., 1994a) were slightly higher (131.7 mM) than in the present trial, where average total VFA were 115 and 116 mM for cows fed HMC and CGC, respectively. This may have been due to a lower sampling frequency in their trials compared to the sampling frequency in the present study (4 vs.1 h). In contrast, lower VFA values were reported in other grazing studies, where total VFA averaged 100 to 104 mM when cows were supplemented a 12 or 16% CP concentrate, respectively (Jones-Endsley et al., 1997).

Molar proportions of VFA followed normal patterns for grazing cows (Berzaghi et al., 1996) (Figure 3.7). No difference was observed between treatments in the molar proportions of acetate and propionate, which averaged 66.1%, and 19.0%, respectively (Table 3.10). Acetate to propionate ratio was not significantly different between treatments, and averaged 3.4 and 3.5. Iso-valerate was the only VFA significantly higher ($P \leq 0.05$) in cows supplemented with CGC (1.3 vs. 1.1%).

Mean ruminal NH_3 N did not differ among treatments. However, the mean NH_3 N concentration was almost 16% lower in cows supplemented with HMC (26.2 mg/dl) compared to CGC (31.0 mg/dl) (Table 3.10). A similar mean NH_3 N (23.2 mg/dl) was reported by Van Vuuren et al. (1993) for cows supplemented with 4.5 kg/d DM of high moisture ear corn. These results support the lack of difference in MUN reported in Experiment 1, when cows were supplemented either HMC, CGC, or FGC.

In both treatments NH_3 N concentration began to increase abruptly approximately 2 h after the beginning of grazing, i.e. 3 h after corn supplementation (Figure 3.8). It continued to increase (gradual increase beyond 5 h), reaching maximum concentrations approximately 6 and

7 h after grazing began, for cows supplemented with HMC and CGC, respectively. Similarly, other workers observed that NH_3 N concentration peaked 8 h after a starchy supplement was fed (Van Vuuren et al., 1986). However, in a study conducted with dry cows, Holden et al. (1994a) suggested that the peak of NH_3 N occurred between 1 and 5 h after dry cows were allowed a new area of pasture during the morning. Differences observed in their study may have been due to the absence of corn supplementation. Thus, the different time in which peak of NH_3 N was observed between studies may suggest that the 2 h lag time between the beginning of grazing and when NH_3 N started to increase in the present study, was caused by corn supplementation plus the readily digestible portion of forages, which supplied enough energy for rumen microbes to optimize NH_3 N utilization at the beginning of the grazing session.

Experiment 3

Grazing behavior. Grazing patterns of the 40 cows as a group were almost identical between days (Figure 3.9). Due to a delay in the p.m. milking, cows began grazing 30 min later in Day 2 compared to Day 1.

Four distinctive peaks of grazing activity (> 50% of the cows actively grazing) occurred during both days. The first two peaks occurred in the afternoon: one immediately after the p.m. milking, which lasted approximately 2 h, and the second intensive grazing activity was observed in the evening, between 1900 and 2030 h. A third, very short peak (less than 30 min) occurred at night, immediately after the a.m. milking, when cows were taken back to the field. The last peak occurred in the morning, between 0730 and 0900 h. Thus, the most intensive grazing activity occurred in the afternoon, immediately after milking and before sunset.

Similar eating patterns were observed by Perera et al. (1986) during summer in lactating Holstein cows in confinement. However, in other studies, where a continuous grazing system was used, only two main peaks of grazing activity were reported: one during mid morning and a second peak during late evening (Rook et al., 1994; Phillips and Leaver, 1986). In the present study, a new area was allowed for grazing every day, after the p.m. milking. Thus, the intensive grazing activity observed early in the afternoon could have been stimulated by the return to pasture after the p.m. milking (Perera et al., 1986) combined with the availability of a new area for grazing.

Grazing patterns did not differ ($P > 0.05$) between high and low milk producing Holstein cows (Table 3.11). However, high producers spent more time lying down ($P \leq 0.05$) compared to low producers (5.5 vs. 4.2 h/d). Observations on the grazing behavior of the eight individual cows confirmed the results with the 40 cows observed as a group. Total average grazing time for the eight cows observed individually was of 6.4 h/d (Table 3.12). A similar grazing time (6.6 h/d) was reported by Phillips and Leaver (1986) in a study conducted with lactating dairy cows.

Therefore, while in the field, cows spent 49% of the time grazing. In the remaining time cows were either standing (1.7 h/d) or lying (4.9 h/d). Although a different management system was used, similar patterns were reviewed by Albright (1993) from a study conducted in New Zealand. Furthermore, 64% of the grazing time occurred in the afternoon (4.1 h/d), and only 36% during the morning (2.3 h/d) (Table 3.12). This results agree with the observations reported in a study conducted by Phillips and Leaver (1986), where the most intense grazing activity occurred after the p.m. milking. However, this does not agree with the results shown by Rook and Huckle (1995), who found no marked differences between the morning and the afternoon grazing time. However, in the same study, cows supplemented with 4 kg/d of concentrate had fewer meals in the morning.

Grazing activity during daylight (5.5 h/d) accounted for 71% of the total daylight hours (9 h), while in the field. In contrast, time spent grazing accounted for only 22% of the time in the field during the 4 h of dark. Therefore, 86% of the total grazing time occurred during daylight. These data agree with data reported by Rook et al. (1994) and Albright (1993), who reported in different studies that 88 and 85% of the total grazing time occurred during daylight. However, different grazing patterns were observed by Seath and Miller (1946). In their study, 50% of the grazing time occurred during daylight when ambient temperature was of 22^{o}C. However, when temperature was of 30^{o}C, only 23% of the grazing time occurred during daylight.

Another characteristic of cow behavior in the present study was the longer continuous period of time that cows spent lying during nighttime compared to daylight (3 vs. 1.8 h) (Table 3.12). Perera et al. (1986) reported that lying was negatively correlated with ambient temperature, and standing was positively correlated with air temperature. In the present study, cows spent more time lying at night, as presumably ground temperature decreased; and remained standing during the day, presumably as a mean of heat dissipation (Perera et al., 1986).

CONCLUSIONS

Under the grazing and management conditions of this study, most of the grazing activity (86%) occurred during daylight, with the major activity occurring in the afternoon (64%). However, cows grazed only 50% of the time while in the field. This, combined with the decrease in milk yield observed in the first weeks of Experiment 1 may suggest that high producing cows may cease grazing before consuming the amount of nutrients required for maintaining milk yield.

Cow performance did not differ when different forms of corn were supplemented. This observation was supported by the lack of difference in the rumen fermentation parameters observed between cows supplemented either with HMC or CGC. However, although not statistically significant, the mean NH_3 N concentration was 16% lower in cows supplemented with HMC, suggesting that it may have improved the efficiency of NH_3 N utilization by rumen microbes. However, no improvement in milk yield was observed. Cows supplemented with the lower level of HMC seemed to have compensated by increasing pasture consumption, which permitted equal responses compared to cows fed a higher amount of corn.

Milk urea N obtained at the end of week 6, 10 d after N fertilization, were significantly higher compared to milk samples from weeks 2 and 10. However, no significant difference was observed between treatments, suggesting once more that the form of corn supplemented did not increase NH_3 N utilization by microbes in the rumen.

Further studies should be conducted to evaluate the effects of processing and harvesting methods of corn in the performance and NH_3 N utilization by rumen microbes of high producing dairy cows intensively grazing high quality pastures.

Table 3.1. Composition of the mineral-vitamin premix[1] supplemented during the study.

Item	Mineral-Vitamin[2] mix
	(%)
Ca	14.5
P	6.5
Mg	2.2
K	3.5
Cl	8.0
Na	6.4
S	3.2
Sodium bicarbonate	18.0
	(ppm)
Mn	1100.0
Zn	1325.0
Fe	265.0
Cu	132.0
I	20.0
Co	3.0
Se	5.0
F	650.0
	(IU/kg)
Vitamin A	110.23
Vitamin E	551.15
Vitamin D_3	0.44

[1]Mineral-vitamin mix (custom-mixed by Southern States Cooperative, Richmond, VA).

[2]Vitamins are expressed in thousands of IU/kg.

Table 3.2. Average characteristics of Holstein cows during the preliminary period (week 0), prior to the beginning of Experiment 1.

	Supplements[1]			
Item	HMCH	FGC	CGC	HMCL
Primiparous, No.	6	6	6	6
Multiparous, No.	3	3	3	3
DIM	114	111	106	98
Milk yield, kg/d	36.6	36.4	36.0	36.4
BW, kg	537	525	504	508
BCS[2]	2.90	2.85	2.85	2.90

[1]HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

[2]BCS = Body condition score.

Table 3.3. Nutrient composition of mixed pastures[1] during the study.

	Month (SD)					
Item	May	(SD)	June	(SD)	July	(SD)
DM, %	23.4	0.66	23.6	2.41	19.0	2.79
Nutrients, % of DM						
OM	89.8	0.40	88.7	0.31	88.3	0.29
CP	19.6	1.69	27.4	3.84	23.9	2.56
NE_L, Mcal/kg[2]	1.68	0.04	1.68	0.07	1.62	0.05
NDF	51.6	3.19	50.7	8.05	56.1	3.19
ADF	25.7	1.22	25.5	2.3	27.8	1.70
Hcel[3]	25.9	2.60	25.2	5.62	28.3	3.27
NFC[4]	14.6	1.49	6.6	4.14	4.3	3.91
Ash	10.2	0.40	11.3	0.31	11.7	0.29
Ca	0.50	0.14	0.54	0.15	0.48	0.07
P	0.37	0.01	0.42	0.02	0.38	0.04
Mg	0.22	0.03	0.27	0.03	0.25	0.02
K	3.7	0.07	4.2	0.11	4.6	0.13
Fe, ppm	130	27.59	142	18.06	102	27.61
Mn, ppm	55.0	12.83	56.0	3.40	49.0	4.97
Zn, ppm	31.0	2.18	38.0	2.36	33.0	4.97
Cu, ppm	4.5	1.50	5.7	0.47	6.3	1.30

[1]Pastures were predominantly orchardgrass, with lesser amounts of Kentucky bluegrass and white clover.

[2]NE_L = 1.0876 - (0.0127 x ADF%).

[3]Hemicellulose = NDF% - ADF%.

[4]Non-fiber carbohydrates = 100 - (CP% + NDF% + EE% + Ash%).

Table 3.4. Nutrient composition of corn supplements used during the study.

	Corn supplement[1]		
Item	HMC	FGC	CGC
DM, %	77.2	94.1	94.0
Nutrients, % of DM[2]			
OM	98.4	98.4	98.4
CP	8.0	8.9	9.6
NE_L, Mcal/kg	2.04	1.96	1.84
NDF	16.8	18.9	22.6
ADF	3.6	4.1	4.3
NFC[5]	69.3	66.3	61.9
EE	4.3	4.3	4.3
Ash	1.6	1.6	1.6
Ca	0.02	0.03	0.03
P	0.32	0.29	0.29
Mg	0.14	0.14	0.14
K	0.35	0.37	0.37
Fe, ppm	30.0	30.0	30.0
Mn, ppm	6.0	5.0	5.0
Zn, ppm	18.0	14.0	14.0
Cu, ppm	4.0	4.0	4.0

[1]HMC = high moisture corn, FGC = finely ground corn, CGC = coarsely ground corn.

[2]OM, NE_L, EE, ash, and macro and micro minerals were obtained from NRC (1989) tables.

[3]Hemicellulose = NDF% - ADF%.

[4]Non-fiber carbohydrates = 100 - (CP% + NDF% + Ash% + EE%).

Table 3.5. Weekly average air temperature and precipitation during the study.

	Month (week)									
Item	May (1)	May (2)	May (3)	June (4)	June (5)	June (6)	June (7)	July (8)	July (9)	July (10)
Air temperature, °C										
Minimum	6.2	9.2	12.8	9.6	12.6	17.0	16.0	16.3	14.8	18.3
Maximum	20.1	21.1	18.3	16.1	24.7	29.0	26.4	28.3	29.2	30.1
Precipitation, mm	18.8	10.9	35.1	41.4	10.7	16.8	13.7	0.5	3.6	14.0

Table 3.6. Nutrient composition of alfalfa-orchardgrass pasture, alfalfa silage, and orchardgrass hay.

	Alf-OG Pasture[1]			
Item	June	July	Alfalfa Silage	OG Hay[2]
DM, %	25.0	25.0	45.6	89.1
Nutrients, % of DM[3]				
OM	87.9	89.4	86.9	90.6
CP	28.8	19.9	20.9	11.9
NEL, Mcal/kg[4]	1.74	1.68	1.30	1.39
NDF	31.6	44.8	46.8	68.7
ADF	21.7	25.8	38.0	35.7
Hcel[5]	9.9	19.0	8.8	33.0
NFC[6]	23.5	20.7	16.5	6.9
EE	4.0	4.0	2.5	3.1
Ash	12.1	10.6	13.1	9.4
Ca	0.91	0.65	1.26	0.27
P	0.44	0.43	0.37	0.32
Mg	0.28	0.25	0.33	0.11
K	4.33	4.06	3.58	2.79
Fe, ppm	126	81	839	89
Mn, ppm	84	52	90	163
Zn, ppm	46	36	41	39
Cu, ppm	11	7	10	19

[1]An alfalfa-orchardgrass pasture was grazed from the last week of June (week 7 of the study) for 3 h every morning until the end of the study (third week of July).

[2]Average nutrient composition of orchardgrass hay during the study.

[3]EE, ash, and macro and micro minerals of orchardgrass hay were obtained from NRC (1989) tables.

[4]NEL for alfalfa-OG pasture and alfalfa silage = 1.044 - (0.0119 x ADF%), NEL for OG hay = 1.0876 - (0.0127 x ADF%).

[5]Hemicellulose = NDF% - ADF%.

[6]Non-fiber carbohydrates = 100 - (CP% + NDF% + Ash% + EE%).

Table 3.7. LS Means of milk production, composition, and MUN in grazing Holstein cows supplemented with different forms and amounts of corn.

	Supplement[1]					P^2 <		
Item	HMCH	FGC	CGC	HMCL	SEM	TRT	TIME	TRTxTIME
Milk yield, kg/d	30.8	29.7	30.1	30.5	1.92	NS	NS	*
3.5% FCM, kg/d	28.3	26.4	28.1	28.1	0.99	NS	NS	*
Composition, %								
Fat	3.13	2.94	3.23	3.10	0.18	NS	NS	*
Protein	2.96	2.99	2.96	2.95	0.08	NS	NS	NS
SNF	8.41	8.35	8.32	8.32	0.30	NS	NS	NS
Yield, kg/d								
Fat	1.02	0.86	0.99	0.94	0.09	NS	**	*
Protein	0.89	0.87	0.87	0.88	0.06	NS	NS	NS
SNF	2.54	2.44	2.47	2.50	0.16	NS	NS	NS
MUN, mg/dl	13.7	15.0	14.3	15.8	1.65	NS	**	**

[1]HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

[2]TRT = effect of treatment, TIME = effect of time (week), TRT x TIME = effect of interaction between treatment and time.

*$P \leq 0.05$.

**$P \leq 0.01$.

Table 3.8. Average BW change and body condition score (BCS) change in lactating grazing Holstein cows supplemented with different forms and amounts of corn.

	Supplement[1]					
Item	HMCH	FGC	CGC	HMCL	SEM	*P* <
Initial BW, kg						
Average	538	504	508	525		
BW change, kg						
From week 0 to 5	26.8[a]	17.2[a]	13.5[a]	2.9[b]	9.5	**
From week 5 to 10	4.0	11.6	3.6	12.9	12.0	NS
From week 0 to 10	30.8	28.8	17.1	15.8	13.0	NS
Initial BCS						
Average	2.90	2.85	2.85	2.85		
BCS change						
From week 0 to 5	- 0.35	- 0.25	- 0.40	- 0.35	0.05	NS
From week 5 to 10	0.15[a]	0.10[a]	0.15[a]	0.00[b]	0.05	*
From week 0 to 10	- 0.20	- 0.15	- 0.25	- 0.35	0.07	NS

[1]Supplements: HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

*$P \leq 0.05$.

**$P \leq 0.01$.

[ab]Means within a row with different superscripts differ.

Table 3.9. Estimated feed intake during weeks 1, 5, and 10 for lactating grazing Holstein cows fed different supplements[2].

	Week 1				Week 5				Week 10			
Intake	HMCH	FGC	CGC	HMCL	HMCH	FGC	CGC	HMCL	HMCH	FGC	CGC	HMCL
	Kg/d of DM											
Pasture	12.4	11.6	11.1	13.0	5.0	2.7	3.1	5.3	10.3	8.7	9.5	11.5
Alfalfa Silage					6.8	6.8	6.8	6.8				
Corn	6.0	6.0	6.0	4.0	6.0	6.0	6.0	4.0	6.0	6.0	6.0	4.0
Hay	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Min-Vit premix	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total DMI	19.5	18.7	18.2	18.1	18.9	16.6	17.0	17.2	17.4	15.8	16.6	16.6

[1]Total DMI (kg/d) = 0.023 x BW + 0.0201 x DIM + 0.286 x 4% FCM - 0.0979 x NDF (Rayburn and Fox, 1993). Pasture intake was calculated from the difference between Total DMI and corn plus hay daily intake. When alfalfa silage was included in the diet, this was also subtracted from total DMI to obtain pasture intake.

[2]HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

Table 3.10. Ruminal fermentation parameters in grazing lactating dairy cows supplemented with high moisture corn or coarsely ground corn.

	Supplement[1]			
Item	HMC	CGC	SEM	*P* <
pH	6.0	6.1	0.04	NS
NH_3 N, mg/dl	26.2	31.0	5.20	NS
Total VFA, mM	115	116	7.46	NS
	(mole/100 moles)			
Acetate	65.8	66.4	0.46	NS
Propionate	19.3	18.7	0.23	NS
Butyrate	11.8	11.2	0.25	NS
Valerate	1.2	1.2	0.03	NS
Isobutyrate	0.7	0.8	0.03	NS
Isovalerate	1.1	1.3	0.03	**
A:P ratio	3.4	3.5	0.06	NS

[1]HMC = 6 kg/d DM of high moisture corn, CGC = 6 kg/d DM of coarsely ground corn.

Table 3.11. Comparison of grazing behavior between high and low milk producing cows.

	Milk Production[1]			
Item (hours/d)	High	Low	SEM	*P* <
Grazing	5.8	6.9	0.24	NS
Lying	5.5	4.2	0.25	*
Standing	1.4	1.7	0.27	NS
Total	12.7	12.8		

*$P \leq 0.05$.

[1]HIGH = Averaged 33 kg/d; LOW = Averaged 21 kg/d.

Table 3.12. Comparison of grazing behavior between the a.m. and p.m. grazing time.

Item	Grazing time[1]				Total	SEM	P <
	a.m.		p.m.				
	(h)	(%)	(h)	(%)	(h)		
Grazing	2.3	35.9	4.1	64.1	6.4	0.12	0.01
Lying	3.0	62.5	1.8	37.5	4.8	0.13	0.01
Standing	1.0	62.5	0.6	37.5	1.6	0.13	0.05
Total	6.3	49.2	6.5	50.8	12.8		

[1]a.m. = time spent in the field after the a.m. milking, p.m. = time spent in the field after the p.m. milking.

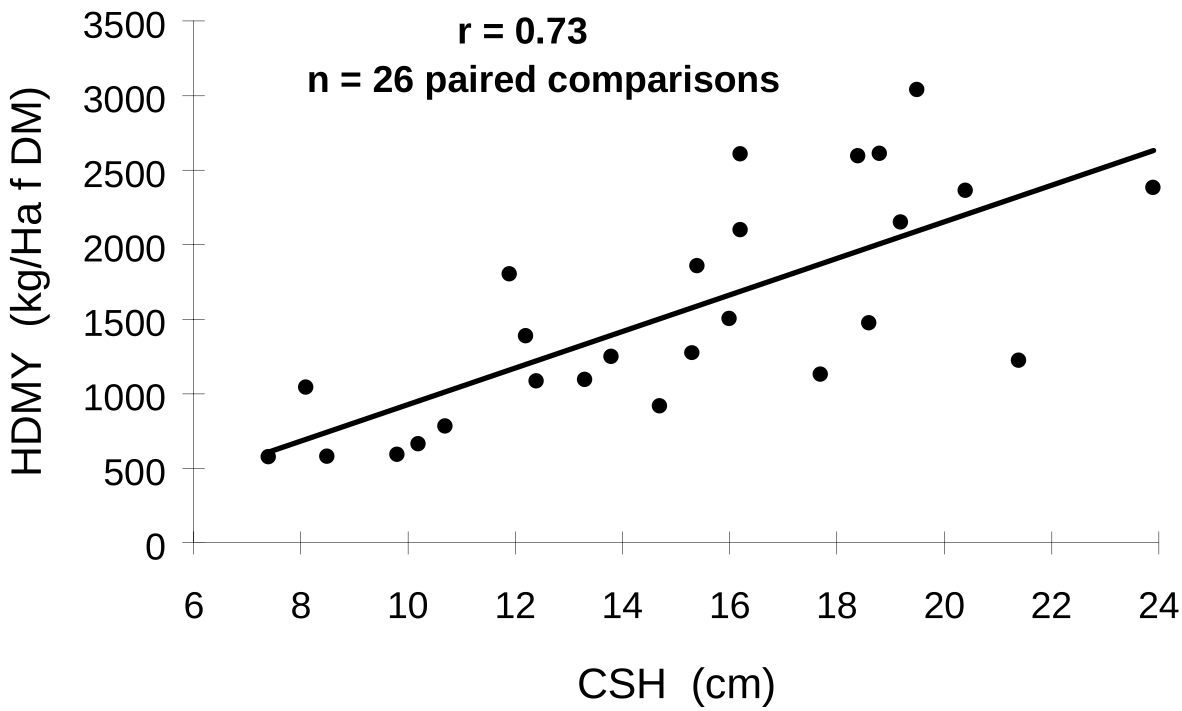

Figure 3.1. Relationship of herbage DM yield (HDMY) and compressed sward height (CSH) of pasture.

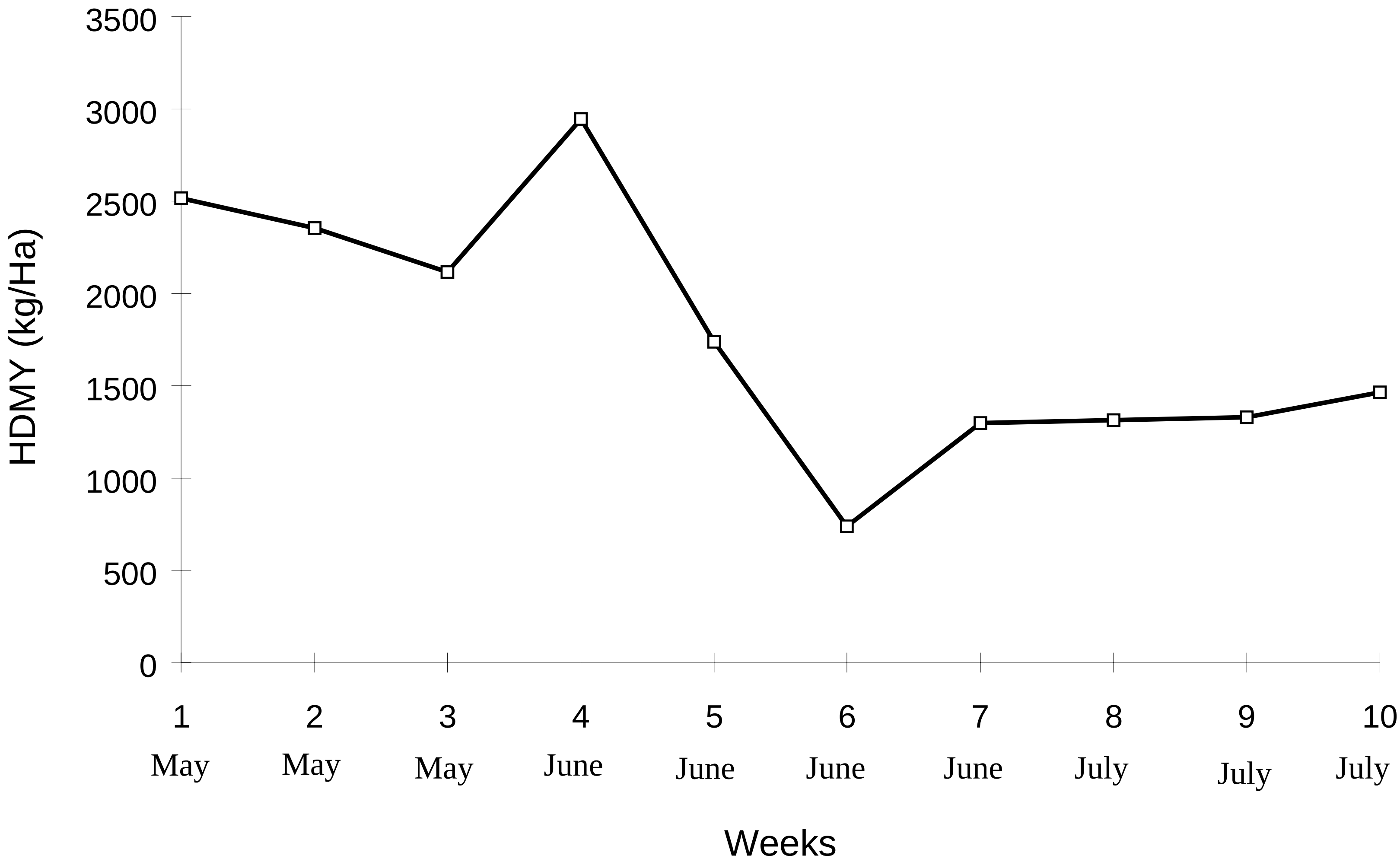

Figure 3.2. Average herbage DM yield (HDMY) during the ten weeks of the study.

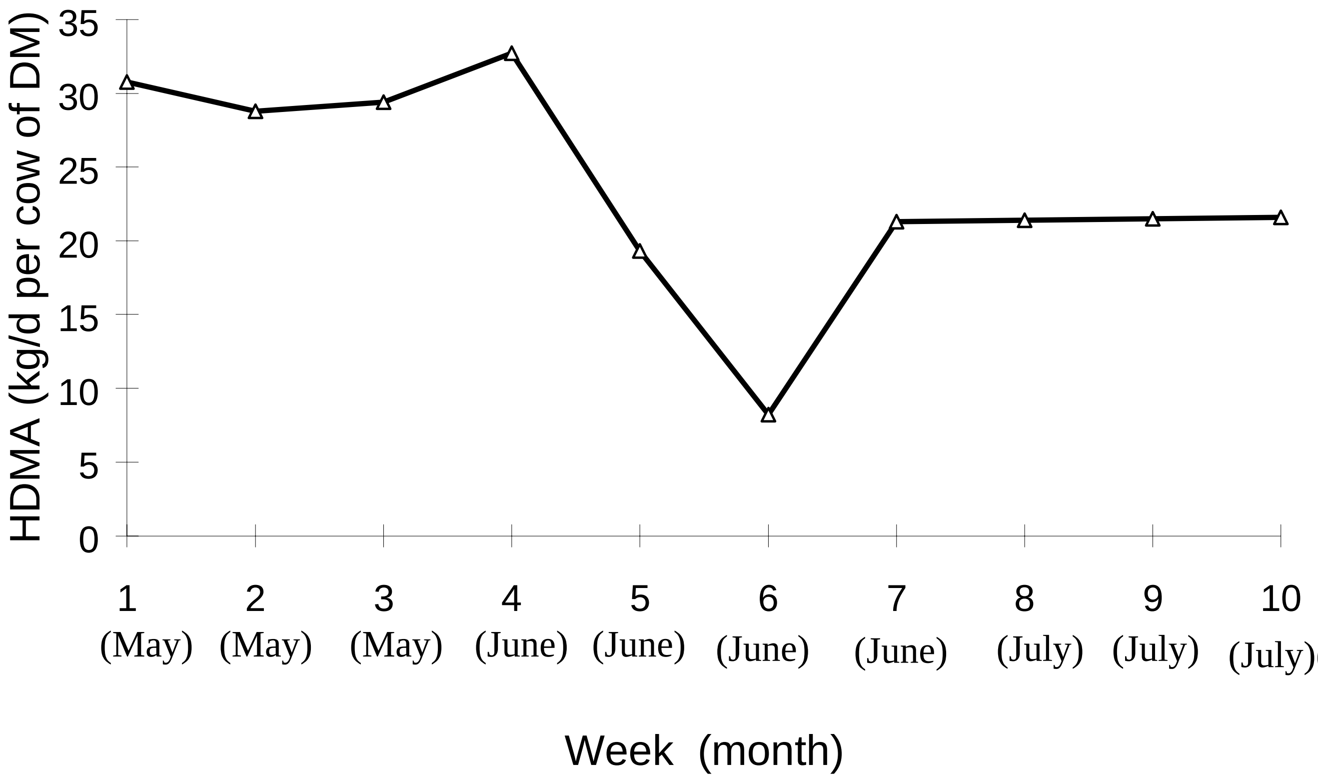

Figure 3.3. Average herbage DM available per cow per day (HDMA) during the ten weeks of the study. During weeks 5 and 6 6.8 kg/d DM of alfalfa silage were offered after corn supplementation. From week 7 to 10 HDMA includes the predominantly orchardgrass pasture and the alfalfa-orchardgrass pasture grazed during 3 h every morning.

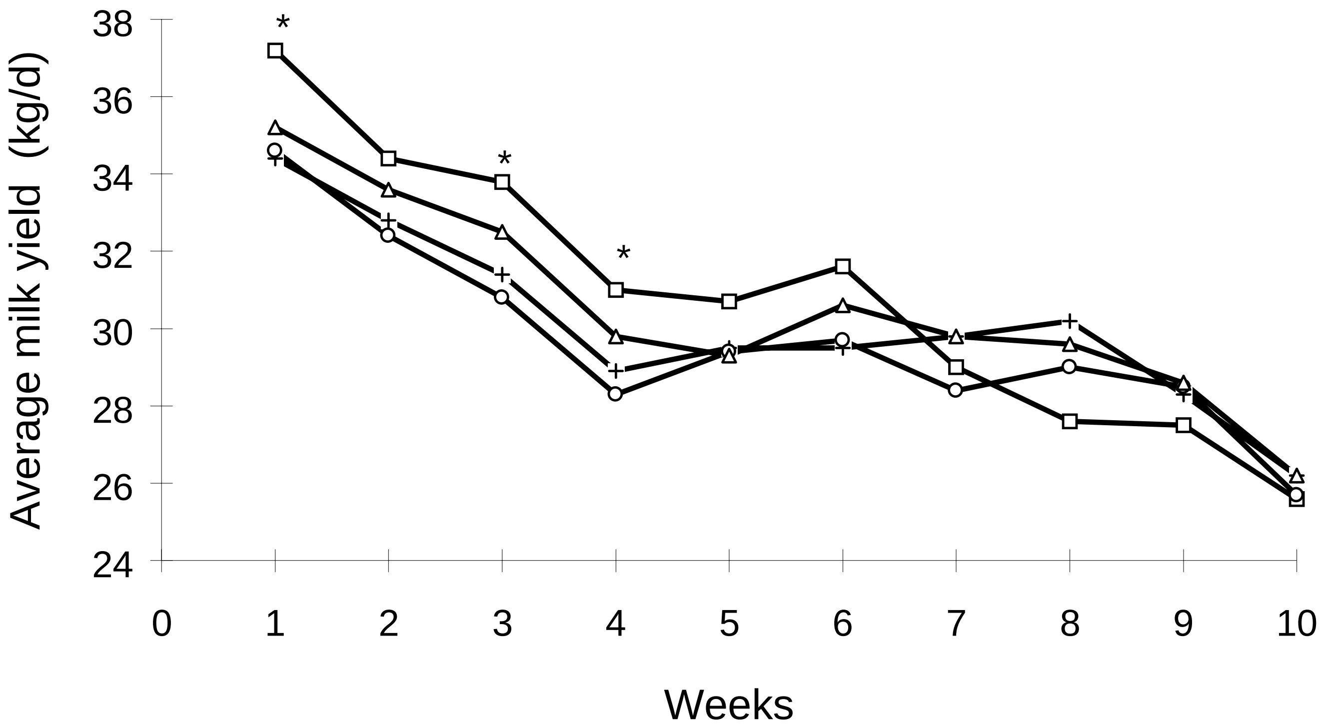

Figure 3.4. Average weekly milk yield for grazing Holstein cows supplemented different forms of corn. Cows were supplemented 6 kg/d DM of high moisture corn (□), 6 kg/d DM of finely ground corn (o), 6 kg/d DM of coarsely ground corn (+), or 4 kg/d DM of high moisture corn (Δ). Cows supplemented with the higher level of high moisture corn produced more milk during weeks 1, 3, and 4 (*) compared to the other treatments.

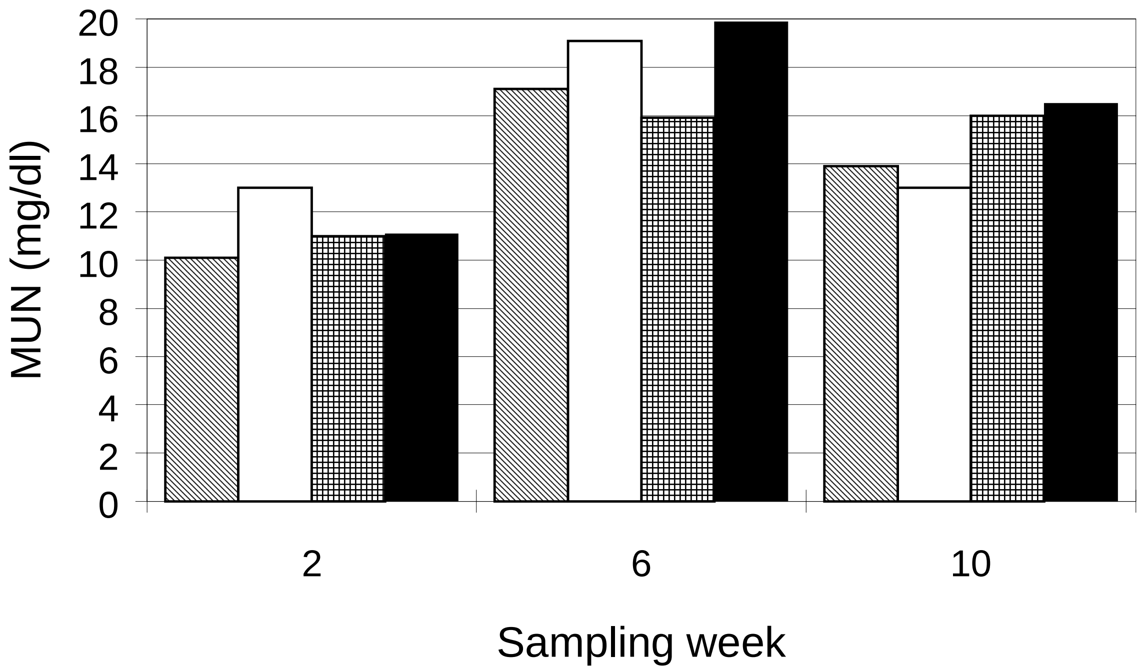

Figure 3.5. Milk urea N (MUN) concentration for grazing Holstein cows supplemented different forms of corn. Cows were supplemented 6 kg/d DM of high moisture corn (diagonal bar), 6 kg/d DM of finely ground corn (open bar), 6 kg/d DM of coarsely ground corn (crosshatched bar), or 4 kg/d DM of high moisture corn (solid bar) during weeks 2, 6, and 10.

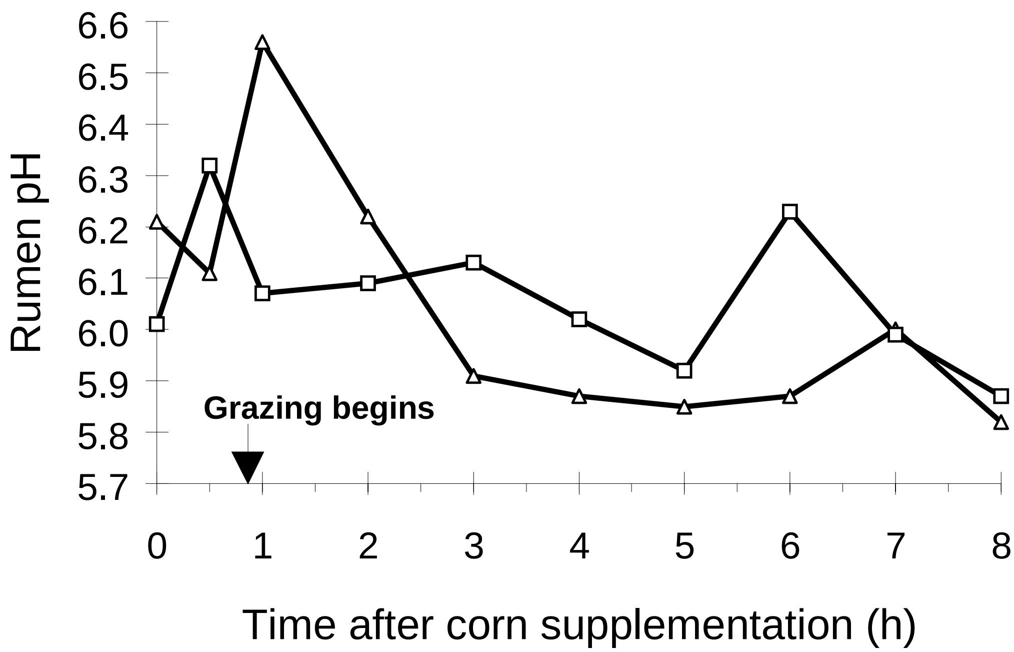

Figure 3.6. Rumen pH changes over time for grazing cows supplemented different forms of corn. Cows were supplemented 6 kg/d DM of high moisture corn (Δ), or 6 kg/d DM of coarsely ground corn (□).

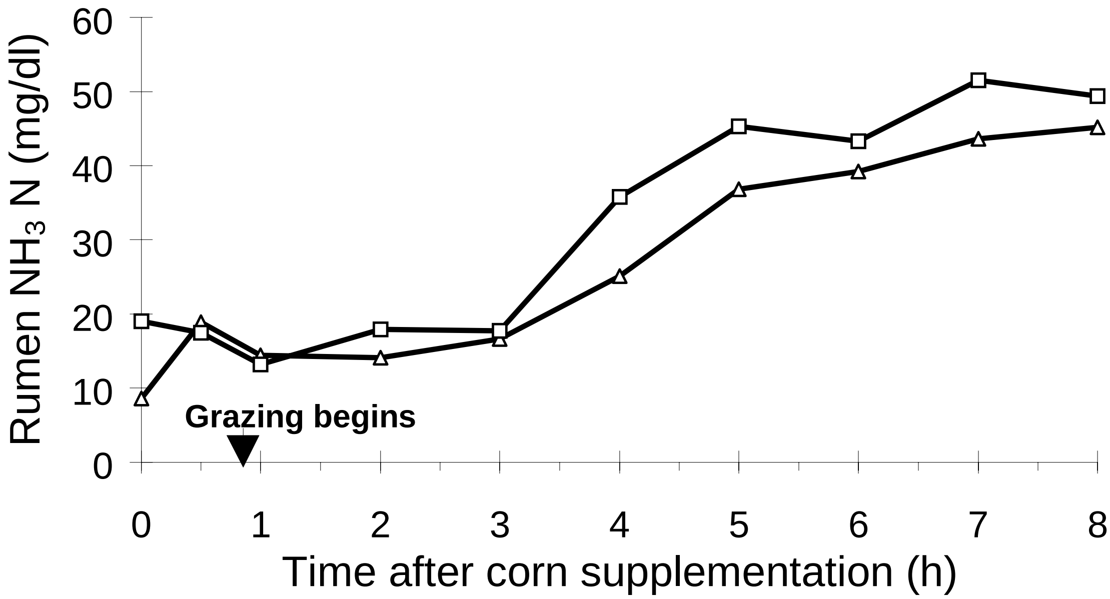

Figure 3.8. Ruminal NH_3 N concentration over time for grazing cows supplemented different forms of corn. Cows were supplemented 6 kg/d of DM of high moisture corn (Δ), or 6 kg/d of DM of coarsely ground corn (□).

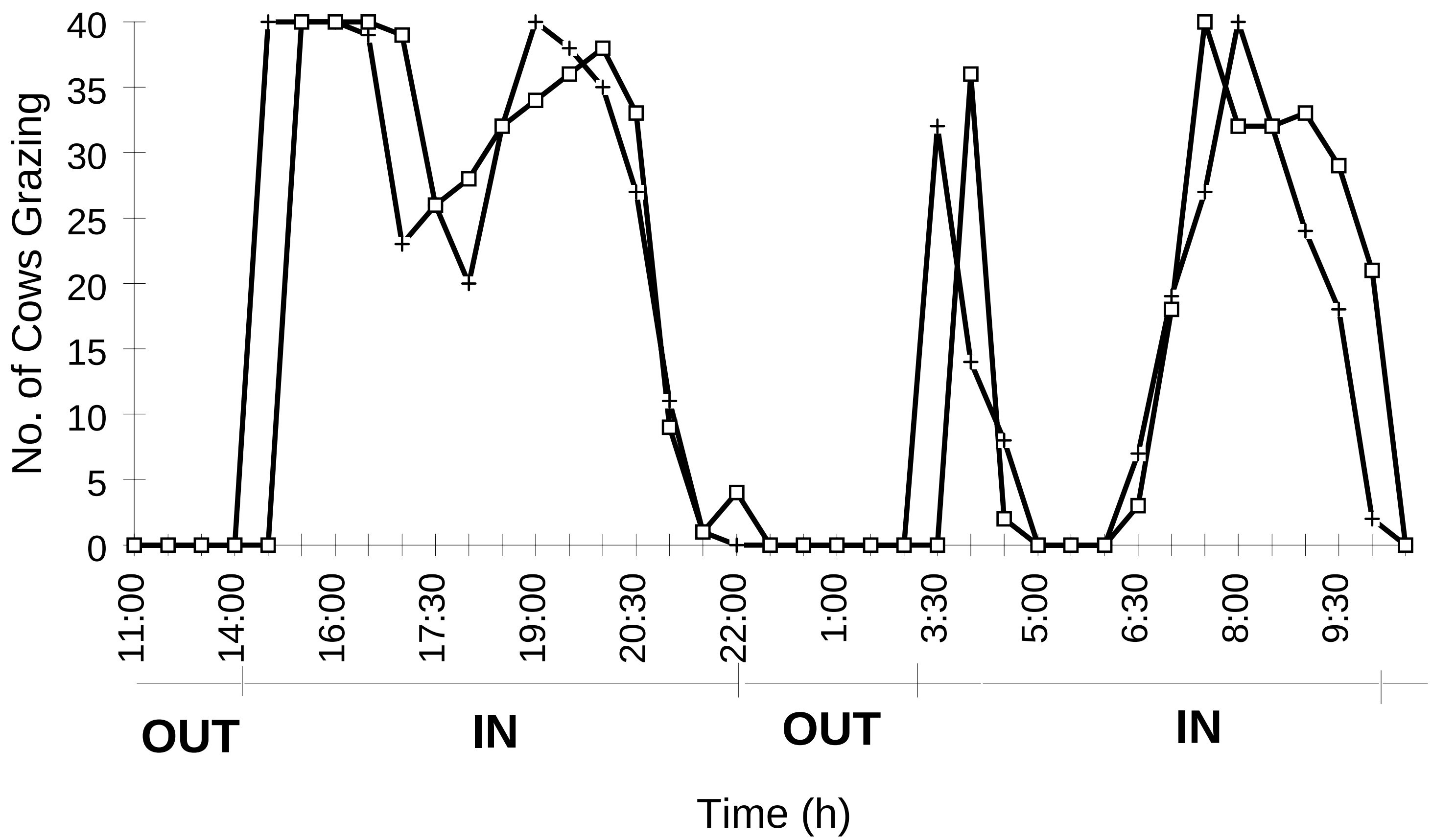

Figure 3.9. Grazing behavior of 40 lactating dairy cows during two consecutive days. Legend: Day1 (+), Day 2 (□); the period when cows were not in the field (OUT), the period when cows were in the pasture (IN).

CHAPTER 4

EFFECTS OF SUPPLEMENTING GRAZING PASTURE TO LACTATING HOLSTEIN COWS FED A TYPICAL TMR DIET

(ABSTRACT)

Little information is available in the literature on the effects of supplementation of high quality pasture to lactating dairy cows fed a TMR diet. This is why beginning in September 1997, a six-week study was conducted to compare performance and income over feed cost of lactating Holstein cows fed either a TMR diet (TMR), TMR in the afternoon and pasture in the morning (PAM), or TMR in the morning and pasture in the afternoon (PPM). Fifty-four Holstein cows in mid-lactation averaging 28.1 kg/d of milk were used in the study. Cows supplemented with pasture spent 8 h/d in the field either after the p.m. or a.m. milking, depending on the treatment. Predominantly orchardgrass pastures with lesser amounts of white clover and Kentucky bluegrass were grazed. Pasture samples were cut once per wk, and weekly composites were analyzed. Compressed sward height and herbage DM yield were estimated once per week. Milk yield was recorded at every milking and samples were collected biweekly. Body condition score and BW was recorded at the beginning and end of the study. Income over feed cost was calculated for each treatment. Compressed sward height and DM yield averaged 12.7 cm and 1397 kg/ha, respectively. Crude protein, NDF, and ADF averaged 18.0, 55.7, and 26.9%, respectively, and NEL was 1.65 Mcal/kg DM. Milk production was slightly but significantly higher for cows on the TMR treatment (29.1 vs. 28.2 and 27.6). No significant difference between treatments was observed in FCM (28.7, 27.1, and 27.3 kg/d), or percentage of milk fat (3.54, 3.42, and 3.46), or protein (3.28, 3.20, and 3.22). Only SNF content (8.77 vs. 8.67, and 8.63 %) was higher in unsupplemented cows. While BW change did not differ among

treatments (23, 32, and 22 kg), body condition score change was greater in cows fed TMR only (0.14 vs. -0.06 and 0.01). The TMR intake was significantly different between treatments, being highest for cows on the TMR treatment and lowest for cows grazing after the p.m. milking (26.6 vs. 20.3 vs. 17.5 kg/d DM). Income over feed cost differed between treatments, and was approximately 15.3 and 9.2% higher for cows grazing high quality pasture during the afternoon compared to cows on TMR and PAM treatments, respectively. Dairy farmers may obtain economical benefits by supplementing grazing pasture to cows fed a typical TMR diet without greatly affecting cow performance.

INTRODUCTION

The use of intensive rotational grazing has been examined by researchers in the US for the last 12 years (Polan et al., 1986; Hoffman et al., 1993; Holden et al., 1994a; Holden et al., 1994b; Holden et al., 1995; Polan et al., 1995; Polan et al., 1996; Polan et al., 1996; Berzaghi et al., 1996; Polan et al., 1997; Polan et al., 1997; Polan and Wark, 1997). However, few studies have been conducted to evaluate the possibilities of using high quality pastures in conjunction with TMR feeding during the grazing season. Taking cows to a pasture during half of the day could reduce feed costs, and benefit herd health during the grazing season. Research with grazing cows suggest that grazing can lessen hoof damage and eye disease compared with the occurrence of these problems while cows are in a dry-lot system (Parker et al., 1993). However, it is not known whether milk production and composition can be maintained by practicing this feeding system.

A USDA survey reported that in recent years only 10 to 20% of dairy producers in the Northeast and upper Midwest dairy states of the US have adopted more intensive grazing management (Hanson et al., 1998). It was concluded from the same survey that the reason for grazing by most of the farmers was that they had always grazed their dairy cattle (Hanson et al., 1998). Furthermore, in a previous survey, Parker et al. (1992) suggested that intensive grazing was not widely adopted because of a lack of confidence in the ability of pastures to provide high quality forage and the lack of information on how to maintain milk production under a grazing system. Thus, a conjunction of TMR and grazing could also serve as a transition period from a dry-lot system to the adoption of intensive grazing management during a particular time of the year.

The objectives of this study were to compare milk production and composition, BW and body condition score (BCS) change, and TMR intake between cows in confinement fed only a TMR diet, and cows fed TMR ad libitum during half of the day, and grazing high quality pasture the other half of the day. Furthermore, recent data would suggest that under certain grazing management conditions, lactating grazing cows spend more time grazing after the p.m. milking (4.1 h/d) compared to after the a.m. milking (2.3 h/d) (Soriano and Polan, 1998). Thus, cow performance and TMR intake were also compared between cows fed TMR during half of the day (morning or afternoon), and supplemented with grazing pasture either during the morning or the afternoon. An economic analysis was also carried out, by comparing income over feed cost (IOFC) between treatments.

MATERIALS AND METHODS

Cows and experimental design

Fifty-four Holstein cows averaging 185 DIM and 28.1 kg/d of milk were used in a 6-wk study. Three treatments were compared during the study. One group of cows totally in confinement was fed a typical TMR diet (TMR). The second group of cows was in confinement eating a typical TMR diet during the morning and grazed a mixed pasture during the afternoon (PPM). The third group of cows were in confinement eating a typical TMR diet during the afternoon, and grazed pasture during the morning (PAM).

Prior to the preliminary period, 30 of the 54 cows were on pasture during 12 consecutive weeks until the wk 1 of August. Later, all cows were confined and fed a TMR diet during 3 wk until the beginning of the experiment.

The experimental design was a restricted randomized complete block design. Cows were blocked according to whether they were previously on pasture or not, and then were stratified according to milk yield, parity, and DIM, after which they were randomly allotted to three groups. Average cow characteristics per treatment are reported in Table 4.1.

Grazing and feeding management

Four fields of approximately 2.7 ha each were used in an intensive rotational manner. Pastures were composed of primarily orchardgrass (*Dactylis glomerata*) with lesser amounts of Kentucky bluegrass (*Poa pratensis*) and white clover (*Trifolium repens*). An electrified nylon string was moved across the field twice daily to allow each group (a.m. and p.m. grazing) to graze a new area of approximately 0.2 ha daily. Prior to the beginning of the study, an average of 5 cm of water was irrigated on each field.

The treatments PPM and PAM spent the same amount of time both in the field and in confinement. Cows in treatment PPM were fed a TMR diet in the morning (0300 to 1200 h), and grazed during the afternoon after the p.m. milking (1500 to 2300 h). Cows in the PAM treatment were in the field during the morning (0300 to 1100 h), and were fed a TMR ration in the afternoon (1500 to 2400 h). Cows in the TMR treatment (TMR) were in confinement the 24 h and were fed only a total mixed ration. The same TMR diet was offered ad libitum to all treatments, while in confinement. Cows on the TMR treatment were fed twice daily: Two thirds were offered after the p.m. milking, and one third after the a.m. milking. Feed refusals were weighed, and the feeding rates were adjusted daily in order to yield orts of about 10%. The TMR intake per treatment was calculated daily from the difference between the amount fed and feed refusals. All cows had continuous access to water always.

Sward measurements and analysis

A minimum of four quadrants (0.25 m^2) were harvested per week using the same technique and device described previously. Before harvesting the herbage, compressed sward height (CSH) was measured in each quadrant using the acrylic disk meter previously described.

Immediately after collection, pasture samples were weighed and oven-dried at 55^o C for 48 h or until constant weight. Herbage DM yield (HDMY) (kg/ha DM) and availability (HDMA) (kg/d per cow of DM) were calculated based on the same formula used in the previous study.

Pasture samples were later ground to pass a 1-mm screen of a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and composites of weekly samples prepared. Composite samples were analyzed for CP (AOAC, 1990), ash (AOAC, 1990), ADF and NDF (Goering and Van Soest, 1970), and for macro and micro minerals by the Cumberland Valley Analytical Services Laboratory (Maugansville, MD). Hemicellulose (Hcel), NE_L, and non-fiber carbohydrates (NDF) were calculated using the following equations:

Hcel (%) = NDF% - ADF%

NE_L (Mcal/kg DM) = 1.0876 - 0.0127 x ADF% (Undersander, 1993)

NFC (%) = 100 - (CP% + NDF% + ash% + EE%) (Mertens, 1992)

The Pennsylvania State University equation for grasses was used to determine NE_L in pastures. Average nutrient composition of pastures is reported in Table 4.2.

Sample collection and analysis

Forages and grains included in the TMR were sampled at weeks 1, 3, and 6 during the study. Immediately after collection, samples were oven dried at 55 ^{o}C in a forced air oven during 48 h or until constant weight. Samples were later ground to pass a 1-mm screen of a Cyclotec mill (Tecator 1093, Hoganas, Sweden), and composited .

Forage samples used in the TMR diet were analyzed for the same nutrients as pasture samples by the Cumberland Valley Analytical Services Laboratory (Maugansville, MD). Nutrient composition of alfalfa and corn silage are shown in Table 4.2. Grain samples were analyzed for CP, ash, ADF, and NDF in the Virginia Tech Forage Testing Laboratory (Blacksburg, VA). The same methods utilized for pasture sample analysis were used, except for NDF where the modified method of Van Soest was used (Van Soest et al., 1991). Nutrient composition of grains is shown in Table 4.3. Chemical composition of the mineral-vitamin premix and the rumen undegradable protein source included in the TMR diet are reported in Tables 4.4 and 4.5, respectively. The TMR had a forage to concentrate ratio of 50:50, and contained 18% CP and 1.69 Mcal/kg of DM of NE_L (Table 4.6).

Cows were milked twice daily, and milk production was electronically recorded at each milking. Milk samples were collected once during the preliminary period, and during wk 1, 3, and 6 of the study. Individual a.m. and p.m. samples were analyzed for fat, protein, and SNF at the Blue Ridge DHIA Laboratory (Blacksburg, VA), by using infrared spectrometry (Multispec Mark I®; Foss Food Technology, Eden Plains, MN).

The BW and BCS were determined in the preliminary period and at the end of the study. Cows were weighed twice during two consecutive days at 0930 h, and the ones that differed in 15 kg or more of BW between days were weighed for a third time. The average between days was calculated. The BCS was determined by four independent evaluators, using the scoring system based on a five-point scale (1 = very thin to 5 = very fat) (Wildman et al., 1982).

Statistical analysis

Data were analyzed by analysis of covariance, using repeated measures, and the General Linear Models Procedure of SAS (1982). The model used in the study was:

$$Y_{ijklm} = \mu + C_i + T_j + PP_k + (T \times PP)_{jk} + COW\ (T \times PP)_{(jk)\ l} + W_m + (W \times T)_{mj} + (W \times C)_{mi} + (W \times PP)_{mk} + (W \times T \times PP)_{mjk} + E_{ijklm}$$

where

Y_{ijklm} =	dependent variable,
μ =	overall mean of Y,
C_i =	covariate adjustment for pretreatment performance,
T_j =	effect of treatment j (j = PPM, PAM, or TMR),
PP_k =	effect of block k (k = cows previously on pasture or not),
$(T \times PP)_{jk}$ =	effect of interaction between treatment j and block k,
$COW\ (T \times PP)_{(jk)\ l}$ =	effect of cow l within treatment j and block k,
W_m =	effect of week m (m = 1, 2, 3, …, 6),
$(W \times T)_{mj}$ =	effect of interaction between week m and treatment j,
$(W \times C)_{mi}$ =	effect of interaction between week m and covariate i,

$(W \times PP)_{mk}$ = effect of interaction between week m and block k,

$(W \times T \times PP)_{mjk}$ = effect of interaction between week m, treatment j, and block k, and

E_{ijklm} = residual error term.

This same statistical model was used to analyze and compare TMR intake between treatments; however, the covariate was not included, as no preliminary data were obtained for TMR intake. Effects of diets were determined by orthogonal contrasts PPM vs. PAM, and TMR vs. (PPM + PAM). All means presented were least squares means.

Economic analysis

Three different scenarios were computed for milk price: high (H), medium (M), and low (L). The medium milk price (14 \$/45.36 kg of milk) was calculated by averaging milk price for the state of Virginia during the last 6 years (1991, '92, '93, '94, '95, and '96) (Virginia Agricultural Statistics Bulletin, 1996). Two dollars were either added or subtracted to the M price to obtain the H (16\$/45.36 kg) and L (12\$/45.36 kg) milk prices.

Three scenarios were also computed for the TMR and pasture cost: high (H), medium (M), and low (L). The M price for TMR was of 123.2 \$/tonne of DM, obtained from the ingredient prices shown in Table 4.7. The ingredient prices were obtained from the Virginia Coop. Extension (1996-97), and from personal communication with Dr. James (1998). The M TMR cost was increased or decreased 20% to obtain a H and L TMR price, respectively.

For the purpose of this study, pastures were assumed to be already established. Thus, a pasture maintenance budget of 94 \$/ha was estimated based on information reported by the Virginia Coop. Extension (1996-97) (Table 4.8). An additional 74.1 \$/ha were added to the pasture maintenance budget in order to account for the land cost, which was based on the typical local rental (equal to a 3% interest of $2471 investment), which is the value of the land (1 ha) in the local area (personal communication with Dr. McGilliard, 1998). Based on data from the previous study, total herbage yield was estimated to be of 6750 kg/ha DM per year. A high (H) and low (L) pasture yield were estimated by adding or subtracting 20% of DM to the M pasture yield. Based on these data, the H, M, and L pasture price were estimated to be 35.4, 24.9, and 19.2 $/tonne of DM, respectively. Thus, pasture cost increased as pasture yield decreased and vice versa. All calculations of IOFC were done on an individual cow basis.

RESULTS AND DISCUSSION

Herbage yield and availability

Compressed sward height averaged 12.7 cm throughout the study. Heights were lower than those reported in the previous chapter; however, HDMY averaged 1397 kg/ha DM, which was similar to HDMY reported at the end of June and July during the previous study. The daily herbage DM availability was calculated based on HDMY and the grazing area allowed daily. Mean HDMY, HDMA, and CSH per week are presented in Table 4.9.

A regression equation for herbage mass as a function of CSH was developed using 24 pairs of observations obtained throughout the study. The following regression equation was obtained:

$$HDMY = 52.157 + 107.83 \times CSH$$

The SE for the intercept and slope were 287.6 and 22.3, respectively. The relationship between CSH and HDMY was linear ($P \leq 0.05$), and the correlation was 0.72 (Figure 4.1). This correlation was similar to the one (0.73) obtained from the same pastures during May, June, and July in the previous study.

Milk production and composition

Least squares means of milk production and composition for the treatment groups are summarized in Table 4.10. Cows in the TMR group produced more milk ($P \leq 0.05$) than cows in the PPM and PAM treatments (29.1 vs. 28.2 and 27.3 kg/d). However, milk production differed ($P \leq 0.05$) only in the first half of the study (Figure 4.2). No difference was observed between treatments in 3.5% FCM (27.8 kg/d).

Fat percentage (3.47%) and fat yield (0.97 kg/d) did not differ among treatments. Similarly, milk protein percentage and yield were not different between treatments, averaging 3.23% and 0.90 kg/d, respectively. In contrast, the SNF percentage was higher in cows fed only TMR compared to PPM and PAM (8.77 vs. 8.63 and 8.67 %).

Body weight change and body condition score

No significant differences were observed in mean BW change throughout the study (25.7 kg) (Table 4.11). However, cows were weighed in the morning, which may have increased the BW of the two groups of cows fed TMR in the morning. In contrast, final BCS and BCS change were higher ($P \leq 0.05$) in cows in TMR compared to cows in PPM and PAM treatments (0.14 vs. -0.06 and 0.01). This would suggest that cows that spent half the day on pasture had a lower proportion of BW deposited in the form of fat, because BW and BW change were similar among treatments.

Estimations of TMR intake

As expected, TMR intake was higher ($P \leq 0.01$) in cows in the TMR group (Table 4.10). Cows in PPM and PAM treatments ate 65.8 and 76.3% of the total TMR DM consumed by cows in the TMR treatment, respectively. Furthermore, cows in PAM treatment consumed almost 3 kg/d DM more TMR ($P \leq 0.01$) than cows in the PPM group. Average TMR intake (kg/d DM) per week is shown in Figure 4.3. Total mixed ration intake was significantly different ($P \leq 0.01$) between treatments in all 6 wk of the study, and it increased linearly throughout the experiment in all groups ($P \leq 0.01$). In addition, difference in TMR intake between PAM and PPM treatment was 1.4 kg/d DM in week 1 ($P \leq 0.05$) and increased to 4.2 kg/d DM ($P \leq 0.01$) in week 6. Thus, cows in PPM treatment decreased TMR intake compared to the PAM group as the study progressed.

Feed intake and nutrient composition of each treatment are shown in Table 4.12. Diet composition in cows in PPM and PAM treatments was estimated based on the following assumptions: the FCM, BW, and BW change did not differ among treatments. Furthermore, milk yield differed only in the first half of the study and the average difference during the study was only 1 kg/d. Thus, based on these observations it may be assumed that cows who spent less time in confinement and grazed during half of the day, compensated for lower TMR intake by consuming pasture. This means that cows in PPM and PAM treatments grazed an average of 8.4 and 5.8 kg/d of herbage DM per cow during the study. Thus, cows in PPM grazed 3 kg/d DM per cow more pasture than cows in PAM treatment. This can be explained from the results observed by Soriano and Polan (1998), where grazing cows supplemented with corn spent more time grazing after the p.m. milking (4.1 h/d) than after the a.m. milking (2.3 h/d). Thus, it suggests that a higher pasture intake occurred after the p.m. milking compared to after the a.m. milking. Based on these assumptions, the nutrient balance was numerically similar among treatments (Table 4.12).

Economic analysis

Feed cost usually accounts for between 35 to 50% of the total cost of production (Schmidt and Pritchard, 1987). Thus, this analysis can have a significant importance when determining the profitability of milk production (Schmidt and Pritchard, 1987). Based on previous assumptions of TMR and pasture intake, IOFC was calculated and compared among treatments.

Income over feed cost was always greater for cows in PPM treatment for all milk and feed price scenarios (Table 4.13). Figures 4.4, 4.5, and 4.6 more clearly show the difference in IOFC between treatments in all three milk price scenarios, when TMR and pasture prices were either high, medium, or low, respectively. Cows in PPM treatment had an IOFC 38 and 22 cents/cow per d greater than cows in TMR and PAM treatments respectively, when milk, TMR, and pasture price were medium. Furthermore, IOFC was 16 cents/cow per d greater in cows in PAM treatment compared to TMR treatment for medium milk, TMR, and pasture price. As cost of TMR decreased, the difference in IOFC between treatments increased (Table 4.13). Thus, IOFC between TMR and PPM treatment was 12.8, 15.3, and 18.7% in favor to the PPM treatment when TMR price varied from H to M to L, and pasture price remained constant (M).

Similar patterns were observed when both TMR and pasture price varied from H to M to L (Figures 4.4, 4.5, and 4.6).

As expected, the combination of the highest milk price with the lowest feed price gave the optimum IOFC, which was 2.86, 3.18, and 3.59 $/cow per day, for cows in treatments TMR, PAM, and PPM, respectively (Figure 4.6). In contrast, the lowest IOFC was observed with a combination of the lowest milk price and the highest feed cost, which was 1.57, 1.63, and 1.76 $/cow per day, for cows in TMR, PAM, and PPM treatment, respectively (Figure 4.4).

CONCLUSIONS

When cows were fed TMR ad libitum during half of the day, and had approximately 15.5 kg/d DM per cow of grazing pasture available during the other half of the day, between 65.8 and 76.3% of the total DMI was covered by the TMR diet, and the rest by pasture. Results from this study showed that the utilization of high quality pastures during the grazing season as a supplement during half of the day, will maintain cow performance without decreasing FCM yield, milk composition, and BW compared to a totally confined system. Furthermore, supplementing grazed pasture to dairy cows consuming a TMR diet, was demonstrated to have an economical advantage over feeding only TMR.

The differences in TMR intake observed during the study suggest that under similar herd management conditions, farmers interested in applying this feeding practice should feed a TMR diet after the a.m. milking, and let cows graze good quality and abundant pastures during the afternoon, following the p.m. milking.

Table 4.1. Cow distribution and characteristics prior to the beginning of the study (week 0).

	Treatments[1]					
Item	PPM	SD	PAM	SD	TMR	SD
Primiparous, No.	11		11		10	
Multiparous, No.	7		7		8	
Milk yield, kg/d	28.9	4.3	29.5	5.5	29.6	5.6
DIM	184	69	186	69	185	69
Body weight, kg	566	62.9	545	53.1	584	67.1
Body condition score	2.9	0.32	2.9	0.29	2.9	0.29

[1]PPM = cows were in confinement eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning; TMR = cows were in confinement the 24 h and were fed a typical TMR diet in the morning and the afternoon.

Table 4.2. Nutrient composition of forages used during the study.

Items	Pasture[1]	Alfalfa Silage	Corn Silage
DM, %	18.0	51.9	35.3
Composition, % DM			
OM	89.1	87.9	95.0
CP	27.0	20.2	11.8
NE_L, Mcal/kg[2]	1.65	1.46	1.55
NDF	55.7	39.3	47.3
ADF	26.9	32.0	27.5
Hcel[3]	28.8	7.3	19.8
NFC[4]	5.0	27.4	32.8
Ash	10.9	12.1	5.0
Ca	0.55	1.43	0.41
P	0.39	0.32	0.22
Mg	0.32	0.31	0.24
K	4.50	2.54	1.68
Fe, ppm	123	875	213
Mn, ppm	51	86	35
Zn, ppm	40	38	25
Cu, ppm	6	7	5

[1]Pastures were predominantly orchardgrass with lesser amounts of Kentucky bluegrass and white clover.

[2]NE_L of pasture = 1.087 - 0.0127 x ADF%; NE_L of alfalfa silage = 1.044 - 0.0131 x ADF%; and NE_L of corn silage = 1.044 - 0.0124 x ADF% (Penn State equations) (Undersander et al., 1993).

[3]Hemicellulose = NDF% - ADF%.

[4]Non-fiber carbohydrates = 100 - (CP% + NDF% + Ash% + EE%).

Table 4.3. Nutrient composition of feedstuffs[1] included in the TMR's concentrate.

Item	HMC	Barley	SBM	CS
DM, %	75.8	92.3	92.3	92.4
Composition, % DM[2]				
OM	98.4	97.4	93.3	95.2
CP	7.7	11.2	49.3	19.4
Ne_L, Mcal/kg	2.04	1.94	1.94	2.23
NDF	12.4	33.8	8.5	44.0
ADF	3.1	12.7	6.2	34.0
NFC[3]	74.0	50.3	34.0	11.8
Ether extract	4.3	2.1	1.5	20.0
Ash	1.6	2.6	6.7	4.8
Ca	0.02	0.05	0.29	0.21
P	0.32	0.38	0.68	0.64
Mg	0.14	0.15	0.28	0.46
K	0.35	0.47	1.98	1.00
Fe, ppm	30	85	175	151
Mn, ppm	6	18	35	19
Zn, ppm	18	19	66	33
Cu, ppm	4	9	24	9

[1]HMC = high moisture corn; SBM = soybean meal; CS = whole cotton seed.

[2]The NE_L, EE and macro and micro minerals were obtained from NRC (1989); NDF and ADF for whole cotton seed were obtained from NRC (1989).

[3]Non-fiber carbohydrates = 100 - (CP% + NDF% + Ash% + EE%).

Table 4.4. Composition of the mineral-vitamin premix[1] included in the TMR.

Item	Mineral-Vitamin[2] mix
	(%)
Ca	14.5
P	6.5
Mg	2.2
K	3.5
Cl	8.0
Na	6.4
S	3.2
Sodium bicarbonate	18.0
	(ppm)
Mn	1100.0
Zn	1325.0
Fe	265.0
Cu	132.0
I	20.0
Co	3.0
Se	5.0
F	650.0
	(IU/kg)
Vitamin A	110.23
Vitamin E	551.15
Vitamin D_3	0.44

[1]Mineral-vitamin mix (custom-mixed by Southern States Cooperative, Richmond, VA).

[2]Vitamins are expressed in thousands of IU/kg.

Table 4.5. Nutrient composition of the rumen undegradable protein source included in the TMR.

Item	ProLak[1]
DM, %	92.3
Composition, % of DM	
OM	86.5
CP	76.2
RDP[2], % of CP	35.0
RUP, % of CP	65.0
ADF	2.7
Ash	13.5
Ca	3.6
P	1.9
Mg	0.1
K	0.3
Fe, ppm	877
Mn, ppm	14.6
Zn, ppm	87
Cu, ppm	16

[1]H. J. Baker & Bro., Inc., Atlanta, GA.

[2]Rumen degradable protein.

Table 4.6. Composition of the TMR fed during the experiment to the TMR, PPM, and PAM treatments[1].

Item	TMR
Ingredients	(% of DM)
Alfalfa silage	34.6
Corn silage	11.8
High moisture corn	15.9
Barley	19.3
Soybean meal	6.1
Whole cottonseed	7.8
ProLak	2.4
Min-Vit premix	1.1
Limestone	0.5
Sodium bicarbonate	0.5
Nutrient composition	(% of DM)
DM, %	61.7
CP	18.0
NE_L, Mcal/kg of DM	1.68
NDF	28.9
ADF	17.6
NFC	40.7
Ether extract	4.0
Ash	6.0
Ca	1.0
P	0.5
Mg	0.3
K	1.5

[1]PPM = cows were in confinement eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning; TMR = cows were in confinement the 24 h and were fed a typical TMR diet in the morning and the afternoon.

Table 4.7. Total mixed ration and feeding cost.

Item	Cost[1]	
Ingredients	($/tonne as fed)	($/tonne of DM)
Alfalfa silage	46.3	89.2
Corn silage	28.0	79.3
High moisture corn	90.0	119
Barley	92.0	99.7
Soybean meal	190	206
Whole cottonseed	150	162
ProLak[2]	500	542
Min-Vit premix[3]	350	350
Limestone	75.0	250
Sodium bicarbonate	300	300
Total TMR cost	76.0	123.2
Labor cost, $ per d[4]	17.4	

[1]All ingredient costs except corn and alfalfa silage (Virginia Coop. Extension, 1996-97) were obtained from personal communication with Dr. James (1998).

[2]Rumen undegradable protein source (H. J. Baker & Bro., Inc., Atlanta, GA).

[3]Mineral-vitamin premix (custom-mixed by Southern States Cooperatives, Richmond, VA).

[4]Labor cost was estimated to be of $8 per h. Labor time was estimated to be of 2.17 h/d for cows on the TMR treatment. This labor time included 30 min/d for cleaning feedbunks (twice per d) and stalls (once per d); 90 min/d for feeding TMR (twice per d); and 10 min/d for moving cows to the parlor and back to the stalls.

Table 4.8. Pasture, grazing, and feeding budget for dairy cows in the PAM and PPM treatments[1].

Budget item	Cost	
Pasture maintenance[2]	($/ha)	($/tonne of DM)
White clover + inoculant[3]	3.8	0.56
N fertilizer (Urea)[4]	57.0	8.44
Fertilizer application	11.9	1.76
Herbicide	8.4	1.24
Fuel, oil, and lube	3.4	0.50
Repairs	9.5	1.41
Land cost[5]	74.1	10.98
Total pasture cost	168	24.9
TMR cost		123.2
Labor cost, $ per d[6]	19.5	

[1]PAM = Cows were in confinement eating a typical TMR diet during the afternoon and grazed pasture during the morning; PPM = Cows were in confinement eating a typical TMR diet during the morning and grazed pasture during the afternoon.

[2]Budget obtained from Virginia Coop. Extension (1996-97).

[3]Reseeding 0.5 kg/ha of white clover plus inoculant once a year.

[4]Fertilization of 100 kg/ha of N per year.

[5]Land cost was estimated based on the typical local rental (74.1 $/ha): about 3% of the interest of 1000$ investment, which is the value of land in the area.

[6]Labor cost was estimated to be of 8 $/h. Labor time was estimated to be of 2.44 h/d. This labor time included 60 min/d for moving electric strings and water once per day, and cows twice per day; 6.0 min/d for measuring compressed sward height using the disk meter technique (twice per wk) and calibrating the disk once per month by clipping and drying pasture samples (Frame, 1981); 20 min/d for cleaning feedbunks and stalls once per d; and 45 min/d for feeding TMR once per d.

Table 4.9. Mean compressed sward height (CSH), herbage DM yield (HDMY), and herbage DM available per day per cow (HDMA) during the study.

	Date				
Item	Sep 1	Sep 8	Sep 15	Sep 26	Oct 1
CSH, cm	10.9	13.1	12.5	11.8	13.9
HDMY, kg/ha	1362	1580	1482	1345	1217
HDMA, kg/d per cow[1]	15.1	17.6	16.5	14.9	13.5

[1]HDMA (kg/d per cow) = (HDMY x Area allowed/d) / No. of cows.

Table 4.10. Comparison of TMR intake, and milk production and composition between lactating Holstein cows on the TMR, PAM, and PPM treatments.

Item	Treatment[1] PPM	PAM	TMR	SEM	$P^2 <$ TRT	TIME	TRTxTIME
TMR intake, kg/d DM	17.5[a]	20.3[b]	26.6[c]	0.15	**	**	**
Milk yield, kg/d	28.2[a]	27.6[a]	29.1[b]	0.30	*	NS	NS
3.5% FCM, kg/d	27.1	27.3	28.7	0.19	NS	*	NS
Milk composition		%					
Fat	3.42	3.46	3.54	0.13	NS	NS	*
Protein	3.20	3.22	3.28	0.05	NS	NS	NS
SNF	8.67[a]	8.63[a]	8.77[b]	0.07	*	NS	NS
		kg/d					
Fat	0.94	0.95	1.01	0.05	NS	*	NS
Protein	0.88	0.88	0.93	0.03	NS	NS	NS
SNF	2.39	2.38	2.50	0.08	NS	NS	NS

[1]PPM = cows fed TMR in the morning and pasture in the afternoon, PAM = cows fed pasture in the morning and TMR in the afternoon, TMR = cows fed only TMR.

[2]TRT = effect of treatment, TIME = effect of time (week), TRTxTIME = effect of interaction between treatment and time.

[abc]Means with different superscripts within rows differ ($P \leq 0.05$). Based on contrasts 1 = PPM vs. PAM; and contrast 2 = TMR vs. (PPM + PAM).

[*]$P \leq 0.05$.

[**]$P \leq 0.01$.

Table 4.11. Mean body weight and body condition score change of lactating Holstein cows on the TMR, PAM, and PPM treatments.

	Treatments[1]			$P <$	
Item	PPM	PAM	TMR	TRT[2]	Contrast[3]
Initial BW, kg	566	545	584		
Final BW, kg	598	567	607	NS	NS
BW change, kg	32	22	23	NS	NS
Initial BCS	2.9	2.9	2.9		
Final BCS	2.8[a]	2.9[a]	3.0[b]	*	*
BCS change	-0.06[a]	0.01[a]	0.14[b]	*	*

[ab]Means within row with different superscripts differ ($P < 0.05$).

[1]PPM = cows were in confinement eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning; TMR = cows were in confinement the 24 h and were fed a typical TMR diet in the morning and the afternoon.

[2]TRT = effect of treatment.

[3]Contrast compares PPM vs. PAM and TMR vs. (PPM + PAM).

*$P \leq 0.05$.

Table 4.12. Proportion of TMR and pasture intake, and nutrient composition of diets fed to cows on the TMR, PAM, and PPM treatments.

	Treatment[1]		
Item	TMR	PAM	PPM
	% of DM		
TMR	100	76.3	65.8
Pasture	0	23.7	34.2
Nutrient composition			
DM, %	61.7	51.3	46.8
	% of DM		
CP	18.0	20.1	21.1
NE_L, Mcal/kg of DM	1.68	1.67	1.67
NDF	28.9	35.5	38.1
ADF	17.6	19.8	20.8
NFC	40.7	32.2	28.5
EE	4.0	3.1	2.6
ash	6.0	7.2	7.7
Ca	1.0	0.9	0.8
P	0.5	0.5	0.5
Mg	0.3	0.3	0.3
K	1.5	2.2	2.5

[1]TMR = cows were in confinement the 24 h and were fed a typical TMR diet in the morning and the afternoon; PPM = cows were in confinement eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning.

Table 4.13. Economic analysis (income over feed cost) for cows in the different treatment groups.

			Treatments[1]		
Milk price	TMR cost[2]	Pasture cost[3]	TMR	PAM	PPM
($/45.36 kg)					
16	H	H	2.09	2.17	2.35
14	H	H	1.83	1.90	2.05
12	H	H	1.57	1.63	1.76
16	M	H	2.42	2.55	2.78
14	M	H	2.11	2.23	2.43
12	M	H	1.81	1.91	2.08
16	L	H	2.86	3.08	3.41
14	L	H	2.50	2.70	2.98
12	L	H	2.14	2.31	2.55
16	H	M	2.09	2.20	2.40
14	H	M	1.83	1.93	2.10
12	H	M	1.57	1.65	1.80
16	M	M	2.42	2.59	2.85
14	M	M	2.11	2.27	2.49
12	M	M	1.81	1.94	2.14
16	L	M	2.86	3.14	3.51
14	L	M	2.50	2.75	3.08
12	L	M	2.14	2.36	2.64
16	H	L	2.09	2.22	2.43
14	H	L	1.83	1.94	2.13
12	H	L	1.57	1.67	1.82
16	M	L	2.42	2.62	2.90
14	M	L	2.11	2.29	2.54
12	M	L	1.81	1.96	2.18
16	L	L	2.86	3.18	3.59
14	L	L	2.50	2.78	3.14
12	L	L	2.14	2.39	2.69

[1]TMR = Cows were in confinement the 24 h, and were fed only a typical TMR diet; PAM = Cows were in confinement eating a typical TMR diet during the afternoon, and grazed pasture during the morning; PPM = Cows were in confinement eating a typical TMR diet during the morning, and grazed pasture during the afternoon.

[2]TMR cost was of 123.2 $/tonne of DM. Medium (M) TMR cost was of 4.25, 3.47, and 3.13 $/cow per d for cows on TMR, PAM, and PPM treatments, respectively (including labor cost). High and low price were obtained by increasing or decreasing 20% the medium TMR price.

[3]Pasture cost was of 24.9 $/tonne of DM. Medium (M) pasture cost was of 1.86 and 1.93 $/cow per d for cows on PAM and PPM treatments, respectively (including labor cost). High and low price were obtained by increasing or decreasing 20% the medium pasture cost.

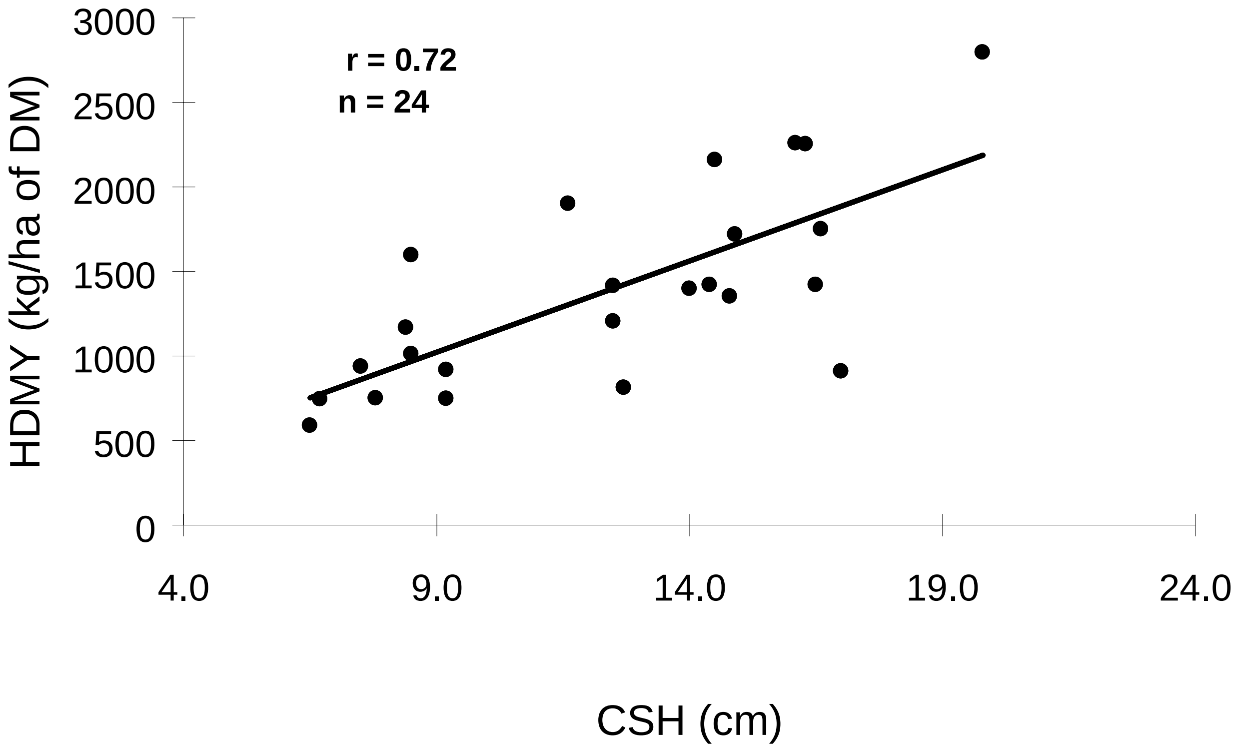

Figure 4.1. Relationship between herbage DM yield (HDMY) and compressed sward height (CSH).

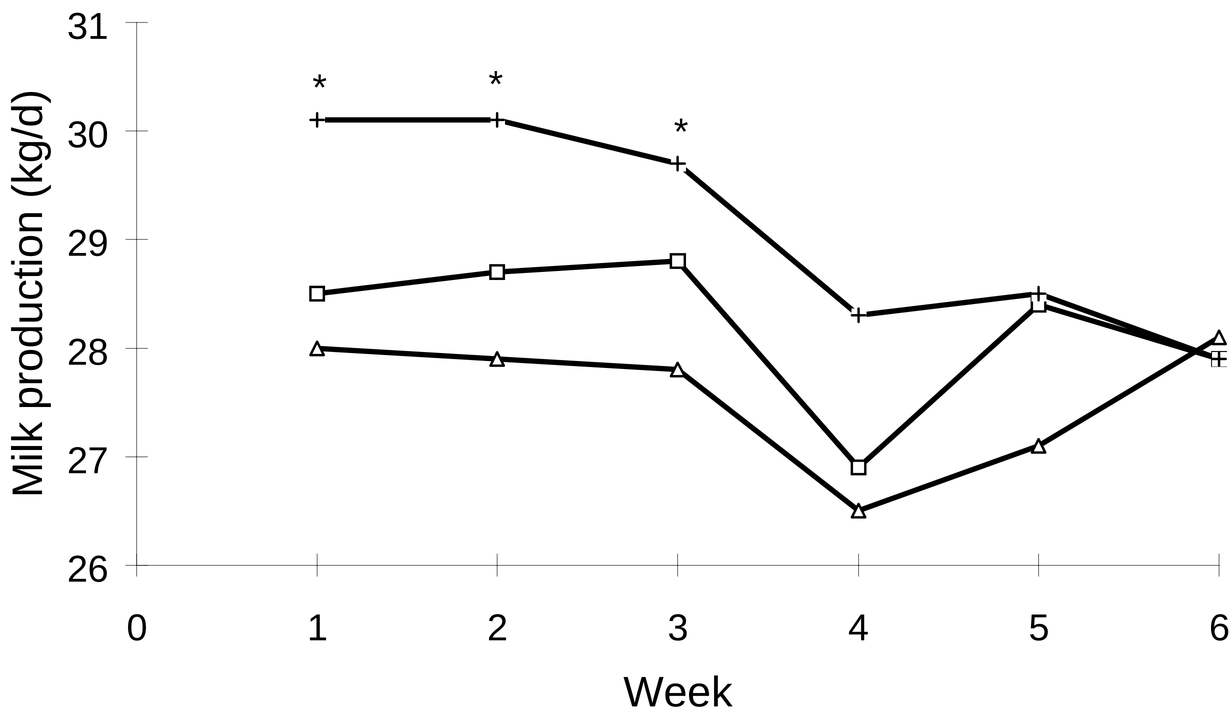

Figure 4.2. Comparison of milk production between Holstein cows in TMR, PPM, and PAM treatments. Treatments consisted of cows that were in confinement the 24 h and were fed a typical TMR diet (TMR) (+); cows that were fed a typical TMR diet in the morning and grazed pasture in the afternoon (PPM) (□); and cows that were fed a typical TMR diet during the afternoon and grazed pasture in the morning (PAM) (Δ). Superscript * indicates weeks at which milk yield was significantly higher for cows on the TMR treatment compared to the PPM + PAM treatments.

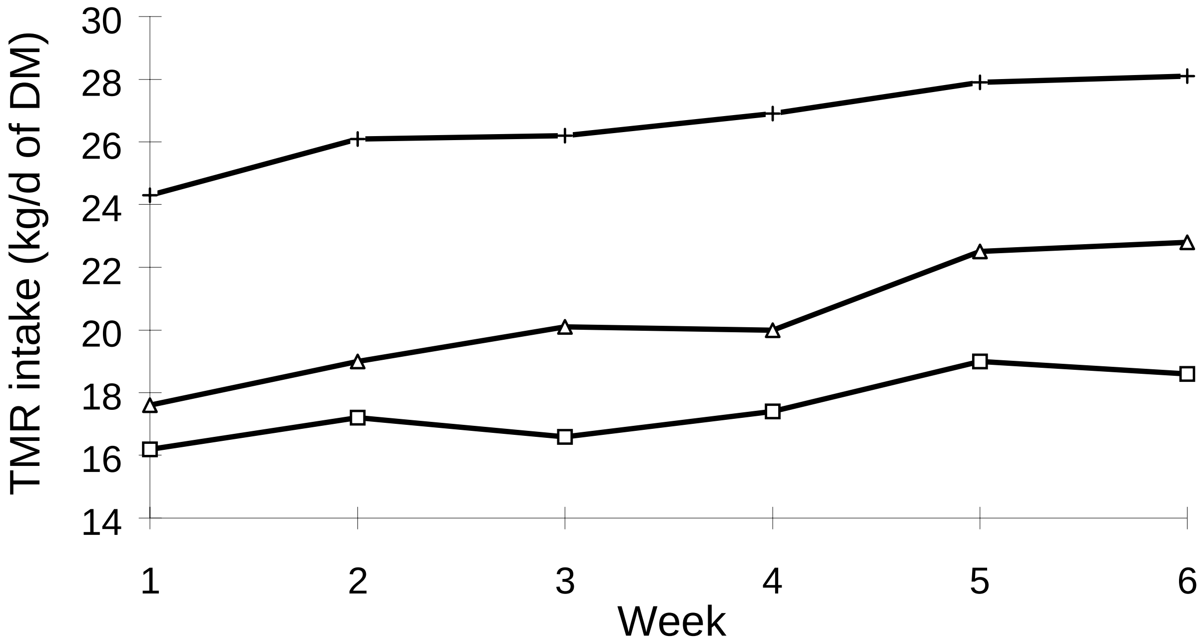

Figure 4.3. Comparison of TMR intake between lactating Holstein cows in the TMR, PPM, and PAM treatments. Treatments consisted of cows that were in confinement eating a typical TMR diet in the morning and grazed in the afternoon (PPM) (□); cows that were in confinement eating a typical TMR diet in the afternoon and grazed pasture in the morning (PAM) (Δ); and cows that were in confinement the 24 h and were fed a typical TMR diet (TMR) (+). TMR intake was significantly different ($P \leq 0.01$) between treatments in all the weeks of the experiment.

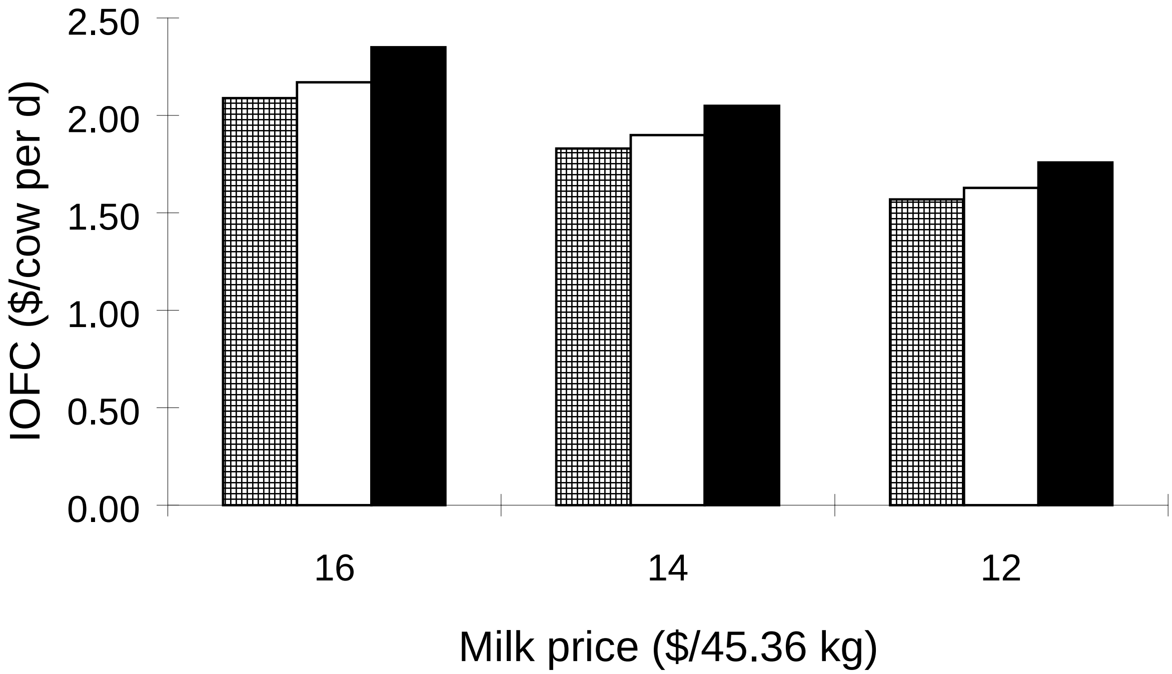

Figure 4.4. Income over feed cost (IOFC) between treatments when TMR and pasture price were high. Cows on TMR treatment (crosshatched bar) were in confinement the 24 h, and were fed a typical TMR diet; cows on PAM treatment (open bar) were in confinement eating a typical TMR diet during the afternoon, and grazed pasture during the morning; cows on PPM treatment (solid bar) were in confinement eating a typical TMR diet during the morning, and grazed pasture during the afternoon.

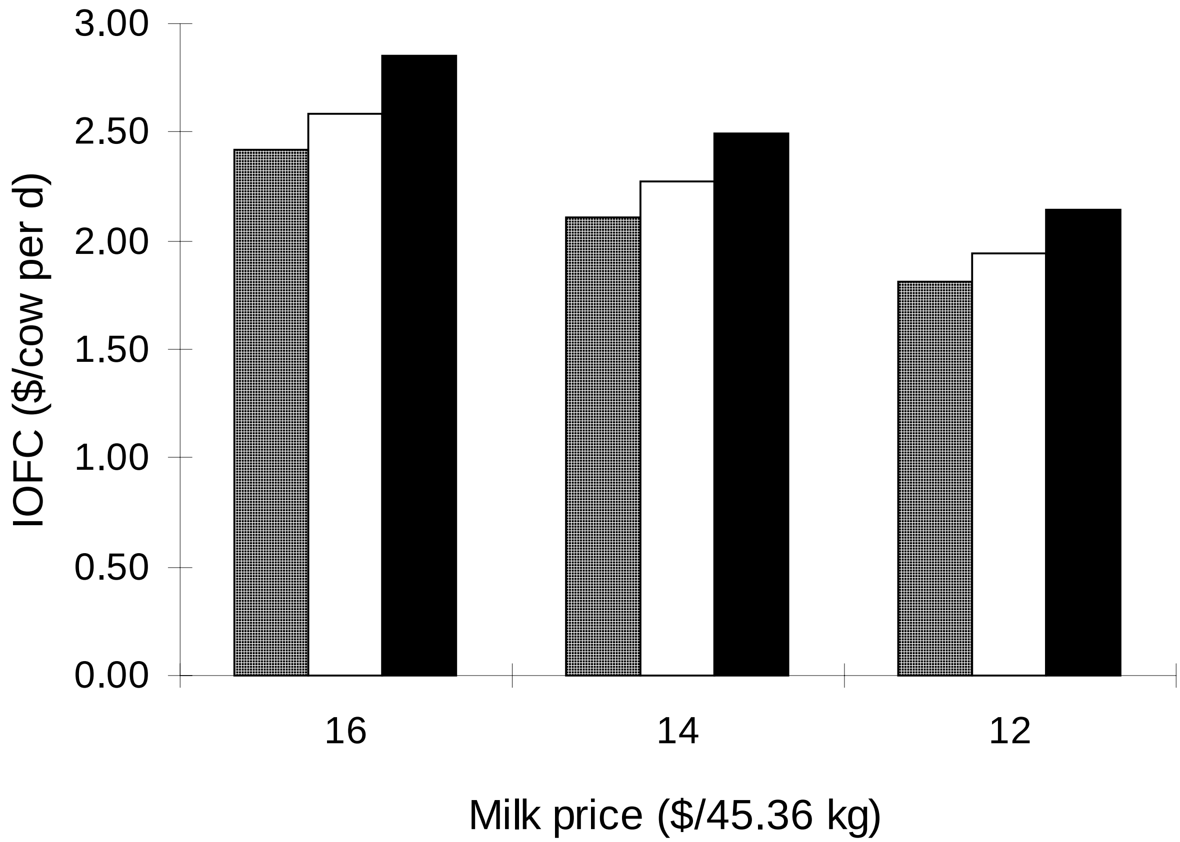

Figure 4.5. Income over feed cost (IOFC) between treatments when TMR and pasture price were medium. Cows on TMR treatment (crosshatched bar) were in confinement the 24 h, and were fed a typical TMR diet; cows on PAM treatment (open bar) were in confinement eating a typical TMR diet during the afternoon, and grazed pasture during the morning; cows on PPM treatment (solid bar) were in confinement eating a typical TMR diet during the morning, and grazed pasture during the afternoon.

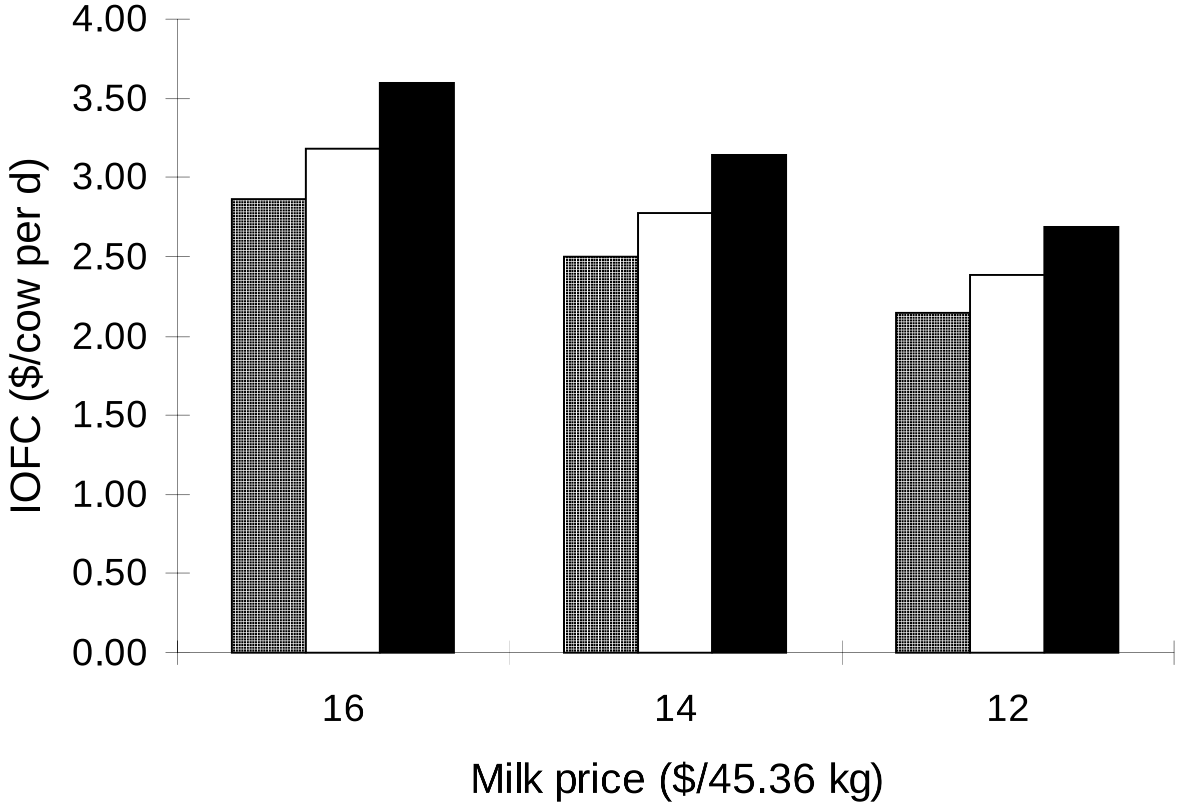

Figure 4.6. Income over feed cost (IOFC) between treatments when TMR and pasture price were low. Cows on TMR treatment (crosshatched bar) were in confinement the 24 h, and were fed a typical TMR diet; cows on PAM treatment (open bar) were in confinement eating a typical TMR diet during the afternoon, and grazed pasture during the morning; cows on PPM treatment (solid bar) were in confinement eating a typical TMR diet during the morning, and grazed pasture during the afternoon.

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APPENDICES

Appendix B. Table 1. Analysis of covariance for the effect of type and amount of corn on milk yield of Holstein cows during Experiment 1 (n = 36).

Source of Variation	DF	Mean Squares	F value	PR > F
Treatment[1]	3	96.842	0.49	0.6927
Covariate[1]	1	8339.736	42.13	0.0001
Parity[1]	1	68.130	0.34	0.5623
Treatment x Parity[1]	3	401.427	2.03	0.1336
Cow (Treatment x Parity)	27	197.942		
Time	9	13.624	0.84	0.5798
Time x Treatment	27	27.286	1.68	0.0220
Time x Covariate	9	48.176	2.97	0.0023
Time x Parity	9	20.014	1.23	0.2746
Time x Treatment x Parity	27	13.881	0.86	0.6746
Residual error	243	16.217		

[1]Using type III MS for Cow (Treatment) as the error term.

Appendix B. Table 2. Analysis of variance for the effect of form and amount of corn on MUN concentration in Holstein cows during Experiment 1 (n = 36).

Source of Variation	DF	Mean Square	F value	PR > F
Treatment[1]	3	20.073	0.82	0.4935
Parity[1]	1	3.420	0.14	0.7113
Treatment x Parity[1]	3	8.237	0.34	0.7989
Cow (Treatment x Parity)	28	24.461		
Time	2	361.625	71.48	0.0001
Time x Treatment	6	20.399	4.03	0.0020
Time x Parity	2	3.210	0.63	0.5340
Time x Treatment x Parity	6	14.879	2.94	0.0145
Residual Error	56	5.059		

[1]Using type III MS Mean Squares for Cow (Treatment) as the error term.

Appendix B. Table 3. Analysis of variance for the effect of type and amount of corn on body weight change of Holstein cows during Experiment 1 (n = 36).

Source of Variation	DF	Mean Squares	F value	PR > F
Treatment[1]	3	3124.420	1.73	0.1827
Parity[1]	1	15066.741	8.36	0.0073
Treatment x Parity[1]	3	2261.605	1.26	0.3087
Cow (Treatment x Parity)	28	1801.556		
Time	2	8890.060	10.80	0.0001
Time x Treatment	6	1982.795	2.41	0.0385
Time x Parity	2	1497.227	1.82	0.1716
Time x Treatment x Parity	6	612.035	0.74	0.6169
Residual error	56	823.032		

[1]Using type III MS for Cow (Treatment) as the error term.

Appendix B. Table 4. Analysis of variance for the effect of type of corn on ruminal NH_3 N concentration in lactating cows during Experiment 2 (n = 4).

Source of Variation	DF	Mean Squares	F value	PR > F
Treatment[1]	1	3726.830	1.37	0.3640
Cow (Treatment)	2	2714.935	9.05	0.0019
Time	9	13414.072	44.73	0.0001
Time x Treatment	9	325.074	1.08	0.4205
Residual error	18	299.864		

[1]Using type III MS for Cow (Treatment) as the error term.

Appendix B. Table 5. Analysis of variance for the effect of milk production on daily grazing time (n = 8).

Source of Variation	DF	Mean Squares	F value	PR > F
Production[1]	1	2.258	2.53	0.1630
Cow (Production)	6	0.893	3.85	0.0090
Time[2]	1	25.383	109.29	0.0001
Time x Production	1	0.195	0.84	0.3691
Residual error	22	0.232		

[1]Using type III MS for Cow (Production) as the error term.

[2]after a.m. milking (a.m.) or after p.m. milking (p.m.).

Appendix C. Table 1. Analysis of covariance for the effect of type of feeding management on milk yield during Study 2 (n = 54).

Source of Variation	DF	Mean Squares	F value	PR > F
Treatment[1]	2	303.393	3.25	0.0475
Covariate[1]	1	17325.775	185.78	0.0001
Prior Pasture[1]	1	26.514	0.28	0.5964
Treatment x Prior Pasture[1]	2	111.341	1.19	0.3121
Cow (Treatment x Prior Pasture)	47	93.258		
Time	5	1.741	0.10	0.9912
Time x Treatment	10	21.218	1.27	0.2489
Time x Covariate	5	5.534	0.33	0.8940
Time x Prior Pasture	5	8.785	0.53	0.7570
Time x Treatment x Prior Pasture	10	16.589	0.99	0.4510
Residual error	235	16.722		
Contrasts				
PPM vs. PAM	1	101.208	1.09	0.3029
TMR vs. (PPM + PAM)	1	504.715	5.41	0.0244
Time x PPM vs. PAM	5	11.989	0.72	0.6113
Time x TMR vs. (PPM + PAM)	5	30.416	1.82	0.1335

[1]Using type III MS for Cow (Treatment) as the error term.

Appendix C. Table 2. Analysis of variance for the effect of type of feeding management on TMR intake during Study 2 (n = 21).

Source of Variation	DF	Mean Squares	F value	PR > F
Treatment[1]	2	905.822	740.84	0.0001
Day (Treatment)	18	1.222		
Time	5	44.997	59.01	0.0001
Time x Treatment	10	2.518	3.30	0.0011
Residual error	90	0.763		
Contrasts				
PPM vs. PAM	1	166.888	136.49	0.0001
TMR vs. (PPM + PAM)	1	1644.756	1345.19	0.0001
Time x PPM vs. PAM	5	4.234	5.55	0.0002
Time x TMR vs. (PPM + PAM)	5	0.803	1.05	0.3920

[1]Using type III MS for Day (Treatment) as the error term.

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