Grazing behavior of rangeland beef cows differing in milk production
by William James Lathrop

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University
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Abstract:
It was the purpose of this study to evaluate the differences in grazing behavior among straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1 SIH) and 75% Simmental-25% Hereford (3S1H) lactating cows. A total of 48 cows were divided into two groups, each group containing six cows from each of the four breed types. The study consisted of four 1 0-d grazing periods starting on July 22 and ending on August 30. Cow weight (BW), calf weight (CW) and milk production (MP) estimates were taken prior to periods 1 and 4., Cow condition was estimated using the weight/height ratio and the average calf age was 105 days (range, 85 to 124 days). Cows roamed freely in a 320 ha pasture with slopes ranging from 5 to 40%. Vibracorders and pedometers were used to estimate time spent grazing and distance traveled, respectively. During periods 1, 2 and 4, the 48 study cows were located on a daily basis between 600-900 hr by the use of an aerial photo map. From the recorded locations, distribution of grazing was calculated for each cow. The overall daily grazing mean was 9*4 hr/d (633 observations). No significant breed type differences were found in daily grazing hours. Breed type means were 9.2, 9.6, 9.2 and 9.3 hr/d for HH, AH, 1 SIH and 3S1H cows, respectively. Daily grazing hours increased from 8.0 hr/d in period 1 to 10.0 hr/d in period 4. Of the cow and calf traits used as covariates, only MP and calf age had any significant effects on time spent grazing. The partial regression coefficients for MP and calf age were .05 hr/d/kg/d and -.02 hr/d/d, respectively (adjusted for BW). The increase in grazing time due to increased MP was mainly between 2400-300 hr. The overall distance traveled mean was 4.7 km/d (82 observations) and followed the same trend as time spent grazing. Two hr/d were spent grazing for every km of travel during the four grazing periods. 1S1H cows traveled less (P<.05) than HH, AH and 3S1H cows. Breed type means were 5.0, 4.8, 4.1 and 4.8 km/d for HH, AH, 1S1H and 321H cows, respectively. The overall distribution mean was 103 ha/cow (47 observations). Breed type was not significant in explaining the variation in distribution of grazing. Breed type means were 105, 115, 93 and 99 ha/cow for HH, AH, 1 SIH and 3S1H cows, respectively. For every kg increase in CW (adjusted for cow condition), distribution of grazing increased by .5 ha (P<.05). Also, for every ha increase in distribution of grazing, cows gained .3 kg in body weight (P<.01>).

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DIFFERING IN MILK PRODUCTION

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A thesis submitted in partial fulfillment
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of

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in

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ABSTRACT

It was the purpose of this study to evaluate the differences in grazing behavior among straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1S1H) and 75% Simmental-25% Hereford (3S1H) lactating cows. A total of 48 cows were divided into two groups, each group containing six cows from each of the four breed types. The study consisted of four 10-d grazing periods starting on July 22 and ending on August 30. Cow weight (BW), calf weight (CW) and milk production (MP) estimates were taken prior to periods 1 and 4. Cow condition was estimated using the weight/height ratio and the average calf age was 105 days (range, 85 to 124 days). Cows roamed freely in a 320 ha pasture with slopes ranging from 5 to 40%. Vibracorders and pedometers were used to estimate time spent grazing and distance traveled, respectively. During periods 1, 2 and 4, the 48 study cows were located on a daily basis between 600-900 hr by the use of an aerial photo map. From the recorded locations, distribution of grazing was calculated for each cow. The overall daily grazing mean was 9.4 hr/d (633 observations). No significant breed type differences were found in daily grazing hours. Breed type means were 9.2, 9.6, 9.2 and 9.3 hr/d for HH, AH, 1S1H and 3S1H cows, respectively. Daily grazing hours increased from 8.0 hr/d in period 1 to 10.0 hr/d in period 4. Of the cow and calf traits used as covariates, only MP and calf age had any significant effects on time spent grazing. The partial regression coefficients for MP and calf age were .05 hr/d/kg/d and -.02 hr/d/d, respectively (adjusted for BW). The increase in grazing time due to increased MP was mainly between 2400-300 hr. The overall distance traveled mean was 4.7 km/d (82 observations) and followed the same trend as time spent grazing. Two hr/d were spent grazing for every km of travel during the four grazing periods. 1S1H cows traveled less (P<.05) than HH, AH and 3S1H cows. Breed type means were 5.0, 4.8, 4.1 and 4.8 km/d for HH, AH, 1S1H and 3S1H cows, respectively. The overall distribution mean was 103 ha/cow (47 observations). Breed type was not significant in explaining the variation in distribution of grazing. Breed type means were 105, 115, 93 and 99 ha/cow for HH, AH, 1S1H and 3S1H cows, respectively. For every kg increase in CW (adjusted for cow condition), distribution of grazing increased by .5 ha (P<.05). Also, for every ha increase in distribution of grazing, cows gained .3 kg in body weight (P<.01).

INTRODUCTION

The range animal grazes over a variety of plant communities. Grazing on any plant community will often result in the selection of certain preferred plant species and plant parts (Arnold and Dudzinski, 1978). This selective process not only affects the composition of forage consumed but also the quantity and quality of the forage available to the animal. As a result of this selective nature, the free-roaming animal spends more time eating and foraging for food than the confined animal. This extra muscular activity can have a considerable impact upon the animal's maintenance energy requirement (Osuji, 1974). It has been estimated that the grazing animal requires 40 to 70% more dietary energy than the confined animal (Graham, 1964; Young and Corbett, 1972; Havstad and Malecheck, 1982). Osuji (1974) suggested that the increase in the animal's maintenance requirement is probably due to the energy costs associated with eating, walking and the work of digestion done by the gut in handling bulky pasture materials. Conventional estimates of the energy required for maintenance have been made with animals housed indoors in respiration chambers. In order to meet the range animal's maintenance requirement, livestock producers need to account for the added costs associated with the animal's activities at pasture.

The energy cost of eating has been estimated to be from 0.26 to 0.83 kcal/kg/hr (Osuji, 1974). Arnold and Dudzinski (1978) reviewed the literature and reported grazing times ranging from 5 to 13 hr/d with the majority of estimates being between 9 to 10 hr/d. The energetic cost of travel on level terrain has been estimated to be from 0.45 to 0.78 kcal/kg/km (Blaxter, 1962; Graham, 1964; Osuji, 1974) with the cost of ascent being ten times as costly (Clapperton, 1964). Cattle have been estimated to travel distances up to 14 km/d (Herbel and Nelson, 1966).

Under extensive range conditions, the increase in energy expenditure could be even greater. Rangelands often exhibit complex combinations of vegetative communities, topography and water distribution. Uniform distribution of grazing is difficult to achieve and large areas of the range go ungrazed while other areas are severly overgrazed. Animals may be forced to travel long distances, possibly over rough terrain, in search of food and water. Uneven use of rangeland can be detrimental to both forage and animal productivity (Arnold and Dudzinski, 1978).

To more fully exploit animal production on rangelands, a more complete understanding of the animal's feeding activities is essential. The major emphasis of this study was to evaluate the grazing behavior of four genotypically different types of beef cattle (straight Hereford, 50% Angus-50% Hereford, 50% Simmental-50% Hereford, 75% Simmental-25% Hereford) grazing rangeland. Past research has shown these four breed types to be different in forage consumption (Kronberg et al., 1983; Wagner et al., 1985), milk production (Casebolt et al., 1984), dam performance and overall productivity (Kress et al. 1984b) and calf performance (Kress et al., 1984b; Kress et al., 1985). The specific objectives were to quantify the major free-roaming diurnal activities (distance traveled and time spent grazing), characterize distribution of grazing and estimate the relationship between animal grazing behavior and animal production.

LITERATURE REVIEW

Grazing is the act of foraging for food and the process involves standing, eating and both horizontal and vertical movement. Behavior can be defined as the response of an animal to its environment. Grazing behavior is concerned with how the process of grazing is affected by the environment in which the animal finds itself.

The focus of this literature review is on the energetic cost of the grazing process to the animal and those animal and environmental factors that influence the degree of energy being expended.

Energy Required For Maintenance

The energy required for maintenance (NEm) can be defined as that amount of feed energy that will result in no loss or gain in body energy and is the amount of energy equivalent to the fasting heat production (NRC, 1984). The heat produced under fasting conditions is proportional to the animal's metabolic rate which increases with increasing body size. Kleiber (1965) estimated that body size was most accurately expressed as body weight raised to the .75 power. Blaxter (1962) reviewed the literature on metabolic rate and found that adult cattle have on the average a metabolic rate of 81 kcal/kg $BW^{.75}$. Currently, the National Research Council (NRC, 1984) is using 77 kcal/kg $BW^{.75}$ as the metabolic rate for cattle as established by Lofgreen and Garrett (1968).

The maintenance requirement is most applicable for animals in nonstressful environments with minimal activity. For the free-roaming animal, the maintenance requirement includes the added energy costs associated with eating, walking, work of digestion (Osuji, 1974) and thermoregulation. Havstad and Malechek (1982) reported an energy expenditure of 161 kcal/kg $BW^{.75}$/day for free-ranging heifers. This was 46% greater than the 110 kcal/kg $BW^{.75}$/day estimated for stall-fed heifers. For grazing sheep, increases in energy expenditure of 30% to 70% have been reported (Young and Corbett, 1972; Osuji, 1974).

The energy cost of merely standing has been estimated to be from 0.06 to 0.38 kcal/kg/hr (Osuji, 1974). Webster and Valks (1966) estimated a 12% increase in energy expenditure of standing over lying. Depending on the type of diet and the measuring techniques used, the energetic cost of eating has been estimated to be from 0.26 to 0.83 kcal/kg/hr (Osuji, 1974). Graham (1964) reported a value of 0.54 kcal/kg/hr for sheep consuming a roughage diet and the cost was the same whether the meal was cut or uncut. This assumes that there is no energetic cost to harvesting the forage, however Young (1966) concluded that the changes in energy expenditure during eating were due to prehension and mastication. Holmes (1978) observed similiar values with cattle consuming cut pasture but observed a mean value of 0.67 kcal/kg/hr for cattle grazing on standing crop. The latter value includes horizontal movement and probably is a more accurate measurement of the energy cost of grazing. The energetic cost of travel on level terrain has been estimated to be between 0.45 and 0.78 kcal/kg/km (Blaxter, 1962; Graham, 1964; Osuji, 1974; Ribeiro, 1977). Clapperton (1964) found the energy cost of horizontal movement increased with speed and the cost of ascent was ten times as costly as that on level terrain.

The process of grazing can be extremely costly if the animal spends an appreciable amount of time on the activity, especially if the animal travels large distances in the process. The situation becomes even worse when animals graze on steep slopes and travel long distances when not grazing. Such conditions are typically found on many mountain rangelands and, as a result, the maintenance requirement of the animal grazing rangeland could be extremely high.

Forage Quantity and Quality

Two of the most important environmental factors influencing animal grazing behavior are forage quantity and quality. There has been general agreement that cattle prefer some plant species over others and select leaf in preference to stem and green material in preference to dry material. The material selected, compared with the material from which it was selected, is usually higher in nitrogen, phosphate and gross energy (Arnold, 1964). This selective nature not only affects the composition of the forage consumed but also has a direct influence upon the quantity and quality of the forage available to the animal.

The quantity of forage consumed (intake) is proportional to the amount of time spent grazing, the biting rate and the bite size. The interrelationships between these variables will vary with the physical structure of the forage (bulk, density, height) (Arnold and Dudzinski, 1978) and with the quality of the forage (green vs. dry, leaf vs. stem). There is no set pattern of adjustment to meet a particular intake level under different forage conditions. In general, as the forage quantity and quality decreases, the animal decreases the size of bite and increases the biting rate (Chacon and Stobbs, 1976; Hendricksen and Minson, 1980). The size of bite taken decreases as quantity of leaf (Chacon and Stobbs, 1976), forage height (Allden and Whittaker, 1970) and forage density (Arnold and Dudzinski, 1978) decreases. Stobbs (1973) stated that a high forage density, a low stem content and a high leaf/height ratio were the major factors influencing bite size of cattle on tropical pastures. The biting rate increases as forage height and availability (Allden and Whittaker, 1970; Scarnecchia et al. 1985) and quantity of leaf (Chacon and Stobbs, 1976) decreases. Uniformity of vegetation could also have a influence on biting rate. Scarnecchia et al. (1985) observed higher biting rates on pastures with uniform forage distribution than on pastures with patchy forage distribution. They concluded that low biting rates were associated with an increase in time spent searching between bites.

The product of bite size and biting rate is intake rate (g/min). As the amount of forage present begins to decline the animals intake rate is at first unaffected; then a stage is reached when forage availability apparently imposes limitations on the rate at which the animal can ingest its feed and intake rate declines (Arnold and Dudzinski, 1978). Allden and Whittaker (1970) found that sheep on pastures containing a mixture of ryegrass, bromegrass and subterraean clover were able to maintain a constant rate of intake when the forage height was between 36.7 and 7.7 cm, but when forage height fell below

7.7 cm the animals were unable to compensate for reduced size of bite by increasing biting rate.

If intake levels are to be maintained, the animal has to increase the amount of time spent grazing to compensate for the decrease in intake rate. Havstad et al. (1983) found that on crested wheatgrass pastures, Angus heifers were able to maintain intake levels when the amount of available forage decreased from 920 to 140 kg DM/ha. On the same type of pasture, Scarnecchia et al. (1985) found that as forage availability decreased from 919 to 144 kg DM/ha, grazing time increased from 6.3 to 10.9 hr/day and biting rate increased from 37 to 50 bites/min. During this same study, Nastis (1979) observed no difference in intake as forage availability decreased. On higher yielding pastures, Allden and Whittaker (1970) found that at forage availabilities greater than 3000 kg DM/ha, both grazing time and rate of intake of green material were relatively constant. As the amount of dry matter fell from 3000 to 500 kg DM/ha, there was a reduction in the rate of consumption from 30 to 5 g/min and a increase in time spent grazing from 6.7 to 11.7 hr/day.

The limit to which the animal can compensate for decreasing forage availability can depend upon the condition of the animal. Arnold and Dudzinski (1978) reviewed the literature and reported grazing times for cattle ranging from 5 to 13 hr/d with the majority falling between 9 to 10 hr/d. Stobbs (1975) reported that fatigue limits the amount of time that can be spent grazing to about 12 hr/day and the number of bites rarely exceeds 36,000/day. Animals in poor condition may not be able to graze as long as those in better shape and as a result be forced to increase their intake rate. Arnold and Birrell (1977) found when forage availability was low, thin sheep consumed a greater amount of forage in the same amount of time as fat sheep by eating 25% faster.

Since intake is limited by both forage digestibility and availability (Arnold, 1964), the maximum level of compensation can be limited by gut fill. Scarnecchia et al. (1985) noted that when forage availability was at its lowest, grazing time was only 9.4% less than the proposed maximun indicated by Stobbs and forage digestibility (35.3% IVOMD) was probabily limiting intake and thus grazing time.

The time of day grazing takes place is also influenced by forage resource. Arnold (1962) found as forage availability decreased, the number of grazing periods decreased from seven to four per day and the average length of a grazing period increased from 1 to 2.5 hr.

Forage quantity and quality also has a major affect on distance traveled. The importance of forage quality and pasture size on distance traveled was illustrated by Anderson and Kothmann (1980) who found that cattle will travel greater distances under a continuous grazing system than under a high-intensity-low-frequency (HILF) grazing system. Heifers under the HILF system traveled 1.5 km/d less than heifers under the continuous system. Crude protein and digestible energy were common independent variables that were significant in explaining the variation in animal travel under both grazing systems. Walker et al. (1985) found different results with mature cows under a short duration grazing system verses a continuous grazing system. Cows on the short duration grazing system tended to walk further than cows on a continuous grazing system. Quinn and Hervey (1970) controlled forage quantity by using different stocking rates and found that yearling steers traveled significantly less on lightly stocked pastures than steers on moderate and heavy stocked pastures. Over a 15 hr observation period, steers averaged 2.4 km in pastures grazed lightly and 3.2 km in pastures grazed moderate and heavy. They noted that although the distance traveled between moderate and heavy stocked pastures was not different, an entirely different manner of travel was observed between the two intensities. The high amount of travel on the moderately stocked pasture was due to a failure to graze while moving to water or from one area to another, whereas movement on the heavy stocked pasture was mostly while grazing. Thus, the distance an animal travels can be a combination of movement while grazing, movement between grazing areas or movement between water and grazing areas. When water is not readily available, travel to and from water can account for most of the distance traveled (Arnold and Dudzinski, 1978).

Climate Influences

Another important environmental factor influencing grazing behavior is the weather. The time of day that grazing takes place and the total daily grazing time is affected mostly by very cold and very hot and humid conditions. Hancock (1954) observed no correlation between temperature and grazing time when temperatures ranged from 10 to 27 C. Dwyer (1961) found that when the average daily temperature exceeded 30 C. for the day, cows did not spend as much time grazing as when the average temperature was lower than 30 C. Malechek and Smith

(1976) noted that during the winter months cows altered their daily behavorial routines in response to changes in the weather. Time spent grazing was positively correlated (0.65) with air temperature (temperature range, -24 to 5 C) and barometric pressure (0.56). Distance traveled was negatively correlated (-0.90) with wind velocity (velocity range, .4 to 15.5 km/hr). Anderson and Kothmann (1980) reported that precipitation, màximim diurnal temperature and vapor pressure were important in explaining the variation in distance traveled under a high-intensity-low-frequency (HILF) grazing system. From July to December, as the temperature decreased from 35 to -3 C., distance traveled decreased from 5.5 to 2.6 km/d . In Great Britain, Rutter (1968) observed that cattle are more restless, graze less and cover more ground while grazing in cold, stormy or windy weather.

Animal Features

Measurable changes in grazing behavior have been attributed to genotype and physiological state of the animal. Animals with higher intake levels, as determined by energy demand, should express a difference in grazing behavior when compared to animals with lower intake levels (Arnold, 1975). Stricklin et al. (1976), using Angus and Charolais x Angus lactating cows, found that the larger Charolais x Angus cows spent more time grazing in both winter and summer than the smaller Angus cows. During the summer months, Angus cows spent 8.5 hr/d grazing while the Charolais x Angus cows spent 9.0 hr/d grazing. Cow weight was not significant in explaining the variation in daily or daylight grazing hours but was significant in explaining night time grazing hours. The partial correlation coefficient between cow weight and night grazing was -0.20, indicating that lighter cows spent more time grazing at night than did heavier cows. Other researchers have also reported a nonsignificant relationship between cow body weight and total daily grazing hours (Brumby, 1959; Stobbs, 1970).

The effect of milk production on grazing time has been documented by several researchers (Hancock, 1954; Arnold and Dudzinski, 1967; Stobbs, 1970). When comparing lactating Jersey and Friesian cows, Brunby (1959) found no differences in grazing time between the two breeds when milk production was held constant. The Friesian cows did have a higher feed intake per kg. of milk produced than the Jersey, but this difference was attributed to a larger maintenance requirement. Stobbs (1970) noted a tendency for high milk producers to have the longest periods of night time grazing. Because of the importance of milk production on grazing time, the differences in grazing time noted by Stricklin et al. (1976) could have been due to the level of milk production.

On a yearlong basis in New Mexico, Herbel and Nelson (1966) found that Hereford cows spent more time grazing, less time walking and traveled less distance than the Santa Gertrudis cows. Breed group means (Hereford, Santa Gertrudis, respectively) were 10.3 and 8.9 hr/d for time spent grazing; 1.6 and 2.9 hr/d for time spent walking; and 7.8 and 12.5 km/d for distance traveled. Hereford cows spent more time grazing at night than Santa Gertrudis cows. Yeates and Murray (1966) have shown that Santa Gertrudis cattle are superior to Herefords in walking ability. Santa Gertrudis heifers had smaller increases in rectal temperature and respiration rate than did Hereford heifers under conditions of forced excercise. They suggested that the superiority of the Santa Gertrudis may be partly due to higher heat tolerance during exercise.

There seems to be no relationship between intake and grazing time (Stobbs, 1970; Hendricksen and Minson, 1980). Kropp et al. (1973) noted this relationship when investigating the differences in grazing time between Hereford, Holstein and Hereford x Holstein yearling heifers. No differences were found between the three breed groups and the breed group with the highest grazing time gained the least weight. Brumby (1959) showed that grazing time required per unit of intake was greater for Jersey cows than for Friesian cows. Since grazing time and intake rate are both measurements of the effort of grazing, the difference between animals with different intake levels could possibly lie in the area of intake rate. It has been demonstrated that structurally larger animals have a larger rumen volume than smaller animals (Nutt et al., 1980) and sheep with a larger rumen volumes tend to consume food faster than sheep with smaller rumen volumes (Purser and Moir, 1966; Warner and Stacy, 1968). Also, thin sheep have been shown to eat faster than fat sheep (Arnold and Birrell, 1977). Arnold (1975) demonstrated that pregnant and lactating sheep achieve higher intake levels than dry sheep primarily by increasing their intake rate and only on abundant pasture do they graze longer. Whether this relationship holds true for cattle is not known.

Physical Environment

Rangelands often exhibit complex combinations of vegetative communities, topography and water distribution. Even distribution of grazing is often difficult to achieve and large areas of the range may go ungrazed while other areas are severely overgrazed. As a result, the total available forage and that forage available to the animal may differ. Because of the importance of forage quantity and quality on grazing time and distance traveled, distribution of grazing becomes an important aspect of grazing behavior.

Due to the grazing animal's selective nature, the type of plant communities and plant species present can have a major influence on the degree of use of any given area. Cattle exhibit a marked preference for some plant communities while avoiding others (Roath and Krueger, 1982). Preference is mainly for grasses but as grasses mature they can be replaced by forbes and browse (Cook and Harris, 1968). In general, cattle prefer to graze those areas in which the proportion of palatable and prefered species is greatest (Miller and Krueger, 1976).

The physical structure of the pasture can also have a major impact on the distribution of grazing. Cook (1966) found that percent palatable species had a positive affect on the degree of area utilization, but several other factors appeared to be more important. Six out of the eleven most important variables were concerned with percent slope. Mueggler(1965) found there to be an interaction between distance upslope and slope steepness. On a 10% slope, where access was mainly from the bottom, 75% of cattle use is likely to be within 810 yards of the foot of the slope. On a 60% slope, 75% of use is likely to be within 35 yards of the foot of the slope.

Since water is essential for life, water availability and distribution is expected to have a major impact on grazing distribution. While there is considerable variation among utilization values for any given distance, there is a consistant trend of decreased utilization as the distance from water increases (Valentine, 1947). Gillen et al. (1984) found that on forested mountain range, cattle preferred areas within 200 m of water and avoided areas greater than 600 m from water. On similar range, Roath and Krueger (1982) reported zero utilization at distances around 1900 m from water.

Other factors that may influence distribution of grazing include aspect of slope (Gonzalez, 1964), surface rock (Gillen, 1983), distance from trails and roads (Roath and Krueger, 1982), salt location and brush thickness (Cook, 1966) and tree cover and down timber (Hedrick et al. 1968).

Because of the complex interactions between the many factors influencing distribution of grazing, no one factor can be used as a reliable indicator in predicting the use of any one area (Gillen, 1983). Using 21 independent variables, Cook (1966) could only account for between 50 to 60% of the variation in the use of mountain slopes. It appears that plant community characteristics, slope gradient and length and water distribution are the major determinants of cattle distribution on mountain ranges (Gillen, 1983). Development of water, fencing and strategic locations for mineral supplements are the primary methods directed towards alleviating these problems (Kothmann, 1980).

The effect of the physical environment on the range animal's grazing behavior has mostly been concerned with distance traveled.

When forage quantity and quality on preferred grazing areas decreases, cattle will travel farther distances, possibly over rough terrain, to less preferred areas. When water is not readily available, travel to and from water can account for most of the distance traveled (Arnold and Dudzinski, 1978). Schmidt (1969), as cited by Arnold and Dudzinski (1978), found that under these conditions cattle may alter their frequency of drinking from one visit to water per day to once every other day. He also observed cattle splitting up into groups, those who forage close to water (nonwalkers) and those who head from water to distant feeding areas (walkers). The only discernible difference between the two groups was the proportion of cows without calves, this being 19% in the nonwalkers and 39% in the walkers. The walkers averaged 16 km/day while the nonwalkers averaged 9.6 km/day.

The importance of the physical environment on time spent grazing is not well documented. Peterson and Woolfolk (1955) observed lower grazing times on a moderately stocked pasture than on a lightly stocked pasture. They concluded that in this case, the shorter grazing time on the moderately stocked pasture resulted from more uniform topography and vegetation subtypes than on the lightly stocked pasture.

MATERIALS AND METHODS

The study was conducted during the summer of 1984 in the Bear Paw Mountains, 32 km southeast of Havre, Montana. The study site had an average elevation of 1300 m with an annual precipitation ranging from 45.7 to 50.8 cm. The pasture used for the study (figure 1) was approximately 320 ha in size and the terrain was rugged with slopes ranging from 5 to 40%. A reservoir and creek were the only sources of available water. A distance of 1.6 km separated the two watering areas. The pasture is traditionally stocked with approximately 250 lactating cows from July 21 to September 1 for a total of 325 AUM's. This can be considered a stocking rate of 1.0 ha/AUM. The pasture is dominated by rough fescue (Festuca scabrella), Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) with an open ponderosa pine (Pinus ponderosa) overstory. Kentucky bluegrass (Poa pratensis) dominated the lowland vegetation.

A total of 48 cows were divided into two groups with each group containing six cows from the following four breed types; straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1S1H) and 75% Simmental-25% Hereford (3S1H). The cows used in this study were between 5 and 8 yr of age and selected at random (within breed type) from the cow herd. All cows were lactating and from a common management background. Calves were sired by either Charolais or Tarentaise bulls. Vibracorders, as described by Stobbs (1970), were used to estimate the amount of time spent grazing. Time spent grazing

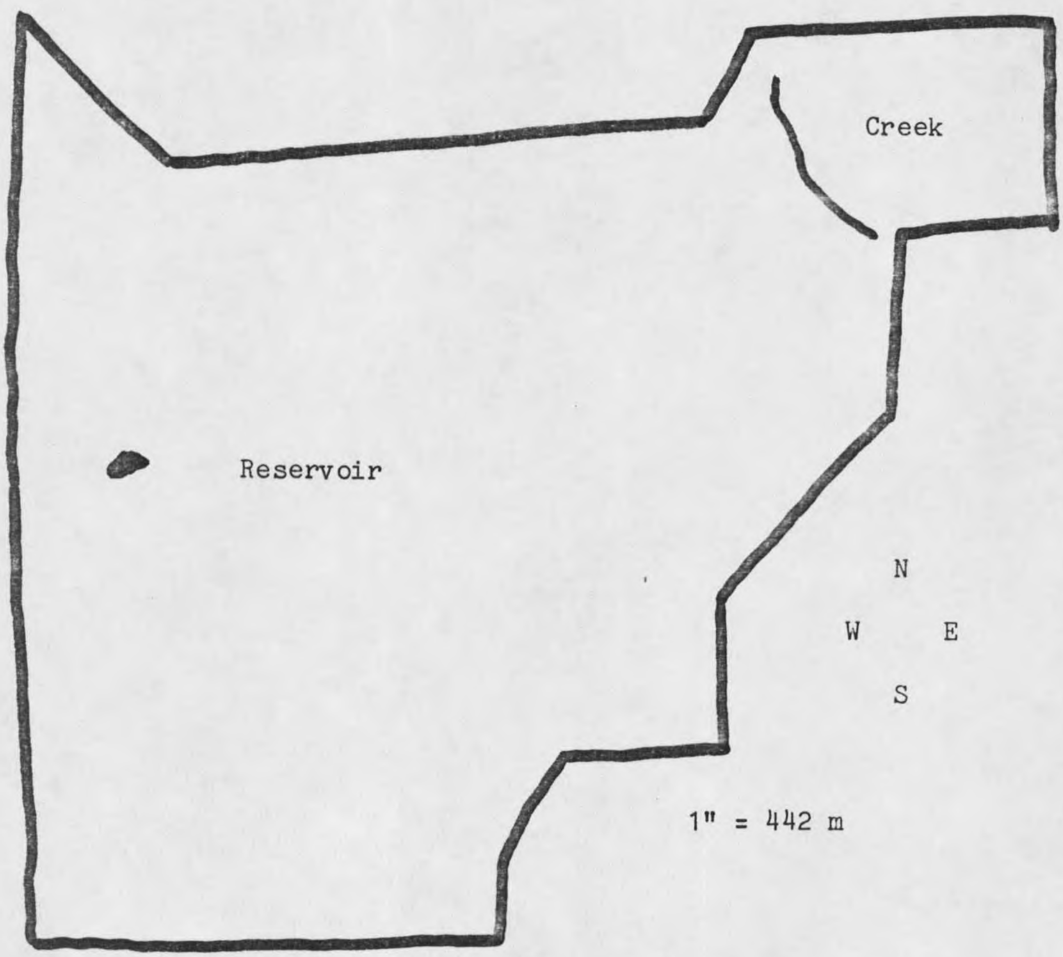

Figure 1. Map of pasture

was determined by estimating grazing activity to the nearest .25 hr. Both daily grazing hours and the time of day grazing took place were analyzed. To estimate the time of day grazing occured, each day's grazing time was divided into eight 3-hr time periods (2400-0300, 0300-0600, 0600-0900, 0900-1200, 1200-1500, 1500-1800, 1800-2100, 2100-2400).

Pedometers, as described by Anderson and Kothmann (1977), were used to estimate distance traveled. Due to the variation in the length of stride between animals, a calibration factor was calculated by dividing the travel distance measured on the pedometer by the actual distance walked. Five cows (Hereford) were walked a distance of 1.6 km to determine the calibration factor. Daily distance traveled was determined by dividing the pedometer readings by the calibration factor (.8) and then adjusting this distance to a 24-hr basis. Use of the calibration factor adjusted for differences in length of stride within breed type, but did not adjust for differences between breed type. Due to the possible variation in measurements between pedometers, animals were randomly assigned pedometers each time equipment changes were made.

The observation dates are shown in table 1. Equipment was rotated between the two groups of cows every 10-d. The study consisted of four 10-d periods starting on July 22 and ending on August 30. Cow weights, calf weights and milk production estimates were taken prior to periods 1 and 4. After a 7 hr. separation time, cow and calf weights were taken and milk production was estimated using the weigh-suckle-weigh technique (Williams et al., 1979a). Milk production was

Table 1. Observation periods and dates

Group	Period	Dates
2	1	July 22 - July 31*
1	2	Aug. 1 - Aug. 10
2	3	Aug. 11 - Aug. 20
1	4	Aug. 21 - Aug. 30*

* Cow weights, calf weights and milk production estimates were taken prior to these periods.

then converted to a 24-hr basis by multiplying the estimate by 3.4. Cow metabolic body weight (body weight $^{.75}$) was calculated but was found to be highly correlated with body weight (.99) and not used in any analyses. Cow condition was expressed as the weight to height ratio (Williams et al., 1979b; Dunn et al., 1983) and the average calf age (stage of lactation) was 105 d (range = 85 to 124 d) at the start of the experiment.

Grazing distribution was monitored during grazing periods 1, 2 and 4. The 48 study cows were located on a daily basis between 600 and 900 hr. Preliminary analysis reveled this to be major period of grazing activity. Each animal's location was determined by and recorded on gridded aerial photo maps. A grazing radius was calculated for each cow by finding the geographic center of the grazing locations and then calculating the average distance from the geographic center to each individual observation as outlined by Hayne (1949) and used by Gillen (1983) to estimate the home range size of free-ranging beef cows. The grazing radius was then squared and multiplied by 3.14 (the area of a circle) to estimate each animal's distribution of grazing.

Using commerically available stock dye, all cows were marked with large numbers to aid in identification. Small portable corrals were placed near water to minimize animal disturbance when equipment changes were made. On days when equipment changes were made, daily grazing and time of day grazing data were not used and animal location was not recorded. The possible number of observations/cow/period for daily grazing hours, time of day grazing hours and distance traveled was eight, eight and one, respectively. For distribution of grazing, only one observation/cow was recorded over the study period.

Statistical Analysis

Data were analyzed by least squares procedures and differences between factor level means were tested using LSD methods (SAS, 1982). All nonsignificant two-way interactions, as revealed by preliminary analyses, were removed to arrive at the final linear models.

A mixed model was employed for analysis of both daily grazing hours and time of day grazing. The linear mathematical model was as follows:

$$Y_{ijklm} = u + B_i + G_j + C_{(k)ij} + P_{(l)j} + D_{(m)lj} + BP_{ilj} + e_{ijklm},$$

where

Y_{ijklm} = an observation

u = the overall mean,

B_i = the fixed effect of the ith breed type,

G_j = the fixed effect of the jth group,

$C_{(k)ij}$ = the random effect of the kth cow within the ith breed within the jth group,

$P_{(l)j}$ = the fixed effect of the lth period within the jth group,

$D_{(m)lj}$ = the fixed effect of the mth day within the lth period within jth group,

BP_{ilj} = the interaction between the ith breed type and the lth period within the jth group,

e_{ijklm} = random error.

Breed type and group were tested using the random effect of cow(breed x group) and all other effects were tested using the residual.

For analysis of distance traveled, a fixed model was employed using breed type, group, period(group), sex of calf and sire breed of calf as fixed main effects. Two-way interactions included breed by period(group) and breed by sire breed of calf.

The model used for distribution of grazing included breed type, sex of calf and sire breed of calf as fixed main effects and no two-way interactions were found to be significant ($P>.10$). Because the number of observations influences the size of the estimated area (Gillen, 1983), the number of observations used to calculate distribution of grazing was included in the model as a continuous independent variable.

Realizing that the mechanisms involved in the control of energy balance are poorly understood (Baile and Forbes, 1974), the point of view taken during this study was that the behavior of the grazing animal is a reflection of it's energy requirement. As a result, cow weight, cow milk production and cow condition, along with calf weight and calf age, were used as covariates whenever possible to determine their effect on daily grazing hours, time of day grazing, distance traveled and distribution of grazing. For daily grazing and time of day grazing, cow(breed x group) was removed from the model and replaced by sex of calf and sire breed of calf. Because the cow and calf measurements were taken prior to periods 1 and 4, the effects of these traits on daily grazing hours, time of day grazing hours and distance traveled are only during these two periods. An average of the measurements recorded in periods 1 and 4 for all the cow and calf traits was used in the distribution model because only one observation/cow for distribution of grazing was measured.

RESULTS AND DISCUSSION

The least-squares analyses of variance for cow body weight, milk production and calf weight for the animals used during the study are presented in table 2. The breed type means and standard errors for these traits (periods 1 and 4) are presented in table 3.

At the beginning of the study (period 1), the Simmental cross cows (1S1H and 3S1H) were heavier ($P<.01$) than the Hereford cows but not heavier than the Angus x Hereford cows. The Angus x Hereford cows were not significantly different from either the Hereford or Simmental cross cows. All breed types maintained their weight for the duration of the trial. Similiar results were observed, at the Northern Agricultural Research Center, by Casebolt (1984). Cow body weight progressively increased during the post peak milk production portion of lactation and no differences were found in the cyclic changes in body weight between these same four breed types.

The Simmental cross cows produced significantly more ($P<.05$) milk than either the HH or AH cows at the start of the study (period 1) (table 3), but by the end of the study (period 4) there was no difference in milk production between the four breed types. The Simmental cross cows significantly decreased in milk production from periods 1 to 4. Casebolt (1984) reported similiar breed type differences with respect to the level of milk production, but found no breed type differences in the shape of the lactation curves. This disagreement, in the shape of the lactation curves, could be

Table 2. Least-squares analyses of variance for cow body weight (BW), milk production (MP) and calf weight (CW)

		Mean squares		
Source	df	BW (kg^2)	MP (kg^2/d^2)	CW (kg^2)
Breed type (B)	3	8068**	59.0**	1535**
Group (G)	1	15475**	21.1	1460**
Period (P)	1	95	57.0*	30856**
Sire breed of calf	1	27045**	20.7	961*
Sex of calf	1	3	1.9	2613**
B x G	3	3760+	17.6	45
B x P	3	336	22.0+	55
Regression				
Age of calf	1	264	7.2	9911**
Residual	79	1471	11.0	199
R^2		0.43	0.32	0.78

+ $P<.10$

* $P<.05$

** $P<.01$

Table 3. Least-squares means and standard errors for cow body weight (BW), milk production (MP) and calf weight (CW)

			Trait[b]		
Period	Breed[a] type	N	BW (kg)	MP (kg/d)	CW (kg)
1	HH	12	552 ± 11[c]	6.8 ± .9[c]	155 ± 4.1[c]
	AH	12	581 ± 11[cd]	7.6 ± 1.0[c]	151 ± 4.2[c]
	1S1H	12	599 ± 12[d]	11.0 ± 1.0[d]	157 ± 4.4[cd]
	3S1H	12	600 ± 11[d]	11.7 ± 1.0[d]	168 ± 4.1[d]
4	HH	12	565 ± 11[c]	6.3 ± .9[c]	188 ± 4.1[e]
	AH	12	581 ± 11[cd]	8.1 ± 1.0[c]	185 ± 4.2[e]
	1S1H	11	594 ± 12[d]	7.6 ± 1.1[c]	196 ± 4.4[ef]
	3S1H	12	601 ± 11[d]	8.8 ± 1.0[c]	206 ± 4.1[f]

[a] HH = Hereford, AH = 50% Angus-50% Hereford, 1S1H = 50% Simmental-50% Hereford, 3S1H = 75% simmental-25% Hereford.

[b] Means in columns with different superscripts are different BW (P<.01), MP and CW (P<.05).

attributed to environmental differences between the two studies or in the number of animals tested and measurements made.

For the duration of the trial, the calves on 3S1H cows were heavier (P<.05) than calves on HH and AH cows but not heavier than calves on 1S1H cows. For all the breed types, calves gained a significant amount of weight from periods 1 to 4.

The two groups of 24 cows used during the study were different in body weight and calf weight but not in milk production. The group means (group 1, group 2) were 570 and 598 kg for body weight; 180 and 172 kg for calf weight; and 9.0 and 8.0 kg/d for milk production. The difference in body weight between the two groups of cows was mainly due to the 3S1H cows in group 2 being 86 kg heavier (P<.01) than the 3S1H cows in group 1. For all breed types, calves in group 1 were heavier (P<.01) than the calves in group 2.

<u>Daily Grazing Hours</u>

The least-squares analysis of variance for daily grazing hours is presented in table 4. Significant sources of variation included group, cow(breed x group), period(group), day(group x period) and breed type x period(group).

The overall daily grazing mean was 9.4 hr/d with a standard deviation of 1.08 hr/d (633 observations). For lactating cows grazing summer rangeland, Dwyer (1961) and Nelson and Furr (1966) found similar estimates of 9.7 and 10.0 hr/d, respectively, while Gonzalez (1964) found a slightly higher estimate of 10.6 hr/d.

No significant differences, in daily grazing hours, were found between the four breed types used in this study. The overall breed

Table 4. Least-squares analysis of variance for daily grazing hours

Source	df	Mean squares
		Daily grazing hours (hr^2/d^2)
Breed type	3	4.8
Group	1	103.1**
Cow(breed x group)	40	7.8**
Period(group)	2	92.4**
Day(group x period)	28	2.4**
Breed x period(group)	6	2.8*
Residual	549	1.2
R^2		0.54

* $P<.05$

** $P<.01$

type means and standard errors were 9.2 ± .09, 9.6 ± .09, 9.2 ± .10 and 9.3 ± .09 hr/d for HH, AH, 1S1H and 3S1H cows, respectively. Kropp et al. (1973) also found no differences in daily grazing time between Hereford, Holstein and Hereford x Holstein non-lactating heifers grazing native range but, Stricklin et al. (1976) found significant differences between lactating Angus and Charolais x Angus cows grazing small alfalfa-orchard-grass pastures. It seems that breed type differences, in the amount of time spent foraging for food, are dependent upon the type of forage being consumed. On rangeland, animals with lower energy demands can graze more selectively and thus have lower intake rates than animals with higher energy demands.

Because two groups of cows were used during the study, comparisions of the period means can only be made between periods 1 vs. 3 and 2 vs. 4. Grazing hours significantly increased ($P<.01$) from periods 1 to 3 and from 2 to 4. The daily grazing hours were 8.0 and 9.8 hr/d for periods 1 and 3, respectively, and 9.5 and 10.0 hr/d for periods 2 and 4, respectively.

The increases in grazing time between periods is likely due to decreases in forage quality and quantity (Arnold, 1960; Allden and Whittaker, 1970; Arnold and Dudzinski, 1978). In Utah, Scarnecchia et al. (1985) found grazing times on crested wheatgrass pastures to increase from 6.3 to 10.9 hr/d when forage availability decreased from 919 to 144 kg DM/ha. Although forage availability was not measured in this study, the stocking rate of 1.0 ha/AUM should have significantly depleted the forage resource.

The interaction between breed and period(group) is presented in table 5. All breed types significantly increased in grazing time from periods 1 to 3 and all breed types except AH increased from periods 2 to 4. AH cows grazed longer ($P<.05$) than HH and 3S1H cows in period 2 and longer than HH, 1S1H and 3S1H cows in period 3. In period 4, the 3S1H cows grazed longer than all the other breed types. It appears that the AH cows responded differently than the other breed types to changes in forage conditions. Because of unequal distribution of grazing on rangeland, forage availability is highly variable from one area to another. Differences between breed types during a particular grazing period could be attributed to the differences in the distribution of grazing. In this case, grazing time is probably dependent upon the forage quality and quantity in the areas they are grazing and the degree of selectivity being expressed.

The residual correlations, between the grazing behavior variables and the cow and calf traits measured in this study, are presented in table 13 (appendix). To determine the effect of the cow body weight, cow milk production, calf weight, calf age and cow condition on daily grazing hours, several analyses were made to avoid the use of any two highly correlated independent variables. Cow body weight was highly correlated with cow condition (.89) and calf weight was highly correlated with calf age (.71).

Of the five cow and calf traits used as covariates in the daily grazing model, only cow milk production and calf age had a significant influence on daily grazing hours (table 6). When age of calf and cow body weight were included in the model, an increase of one kg/d above the mean level of milk production (8.5 kg/d) caused a $.05 \pm .03$ hr/d

Table 5. Least-square means and standard errors for daily grazing hours (hr/d) of the interaction between breed and period(group)[b]

	Group			
	2		1	
Breed[a] Type	Period 1	Period 3	Period 2	Period 4
HH	8.3 ± .17[c] (48)	9.9 ± .15[ef] (48)	9.1 ± .17[c] (41)	9.7 ± .21[f] (31)
AH	8.1 ± .21[c] (31)	10.4 ± .16[g] (46)	10.0 ± .20[de] (34)	10.0 ± .17[ef] (43)
1S1H	8.0 ± .24[c] (32)	9.1 ± .24[d] (30)	9.5 ± .20[ce] (36)	10.0 ± .17[f] (43)
3S1H	7.9 ± .19[c] (39)	9.7 ± .17[df] (44)	9.4 ± .16[c] (47)	10.4 ± .18[h] (40)

[a] Refer to footnote in table 3.

[b] Means in rows and columns (within group) with different superscripts are different ($P<.05$). Number of observations in parenthesis.

Table 6. Effects of covariates on daily grazing hours

Covariate	Partial regression coefficient
Age of calf	-.02 hr/d/d**
Milk production	.05 hr/d/kg/d*
Cow body weight	-.003 hr/d/kg
Cow condition (wt/ht)	-.12 hr/d/kg/cm
Calf weight	-.003 hr/d/kg

* $P<.05$

** $P<.01$

increase in daily grazing hours. Thus, more time grazing is required to support the energy costs associated with increased levels of milk production. Using .67 kcal/hr as the energy cost of grazing (Holmes, 1978), the increase in the animal's maintenance requirement would only be .04 kcal/kg of milk produced. Therefore, the influence milk production has on the energy cost of grazing is minimal. Also, for every one day increase above the average calf age (105 d), daily grazing hours decreased by .02 ± .01 hr/d ($P<.01$). The negative effect of calf age could possibly be due to the cows stage of lactation. Cows with older calves were in a later stage of lactation and produced less milk than cows with younger calves.

Considering all the independent variables together, age of calf had the most important influence on daily grazing hours. The standard partial regression coefficients for age of calf, milk production, cow body weight, cow condition and calf weight were -.07, .06, -.04, -.01

and -.01, respectively. Stricklin et al. (1976) found similar relationships between cow weight and calf weight and daily grazing hours however; calf age was not a significant source of variation and the partial correlation was positive (.23). Stricklin's study was conducted on small pastures during May and June with young calves. Under these conditions, the stage of lactation may not be as important as observed in this study.

Time of Day Grazing

The least-squares analyses of variance for the time of day grazing took place are presented in tables 7 and 8. As with daily grazing hours, cow and day were important sources of variation in time of day grazing. Breed type was significant during the 900-1200 hr time period and period(group) was significant in almost all of the 3-hr time periods studied. The interaction between breed and period(group) was important (P<.05) during 300-600 and 1800-2100 hr.

The overall time of day grazing means are presented in figure 2. The majority of grazing took place between 600-900 and 1800-2400 hr. Secondary periods of grazing ranging from .5 (2400-300 hr) to .9 hr (1500-1800 hr)were recorded.

A similar pattern of grazing activity was observed by Nelson and Furr (1966) using lactating cows and Kropp et al (1973) using heifers on summer rangeland in Oklahoma. Also using lactating cows in Oklahoma, Dwyer (1961) found similar results with respect to the major grazing periods, but cows in their study grazed more in the early morning and less during the afternoon than the cows used in this study.

Table 7. Least-squares analyses of variance for time of day grazing (2400-1200 hr).

		Mean squares			
		Time of day grazing (hr^2)			
		Time of Day (x 100 hr)			
Source	df	24-3	3-6	6-9	9-12
Breed type	3	6	75	93	153+
Group	1	339*	81	714**	1191**
Cow(breed x group)	40	53**	94**	90**	65**
Period(group)	2	240**	299**	748**	757**
Day(group x period)	28	54*	77**	62**	88**
Breed x period(group)	6	23	68*	51	12
Residual	549	31	25	30	34
R^2		0.22	0.35	0.35	0.30

+ P<.10

* P<.05

** P<.01

Table 8. Least-square analyses of variance for time of day grazing (1200-2400 hr).

		Mean squares			
		Time of day grazing (hr^2)			
		Time of day (x 100)			
Source	df	12-15	15-18	18-21	21-24
Breed type	3	100	31	119	20
Group	1	83	528^{*}	302	710^{*}
Cow(breed x group)	40	103^{**}	116^{**}	155^{**}	123^{**}
Period(group)	2	175^{*}	18	924^{**}	136^{+}
Day(group x period)	28	78^{*}	127^{**}	73^{**}	163^{**}
Breed x period(group)	6	92^{+}	82^{+}	178^{**}	96^{+}
Residual	549	47	45	35	49
R^2		0.22	0.29	0.39	0.29

$^{+}$ P<.10

* P<.05

** P<.01

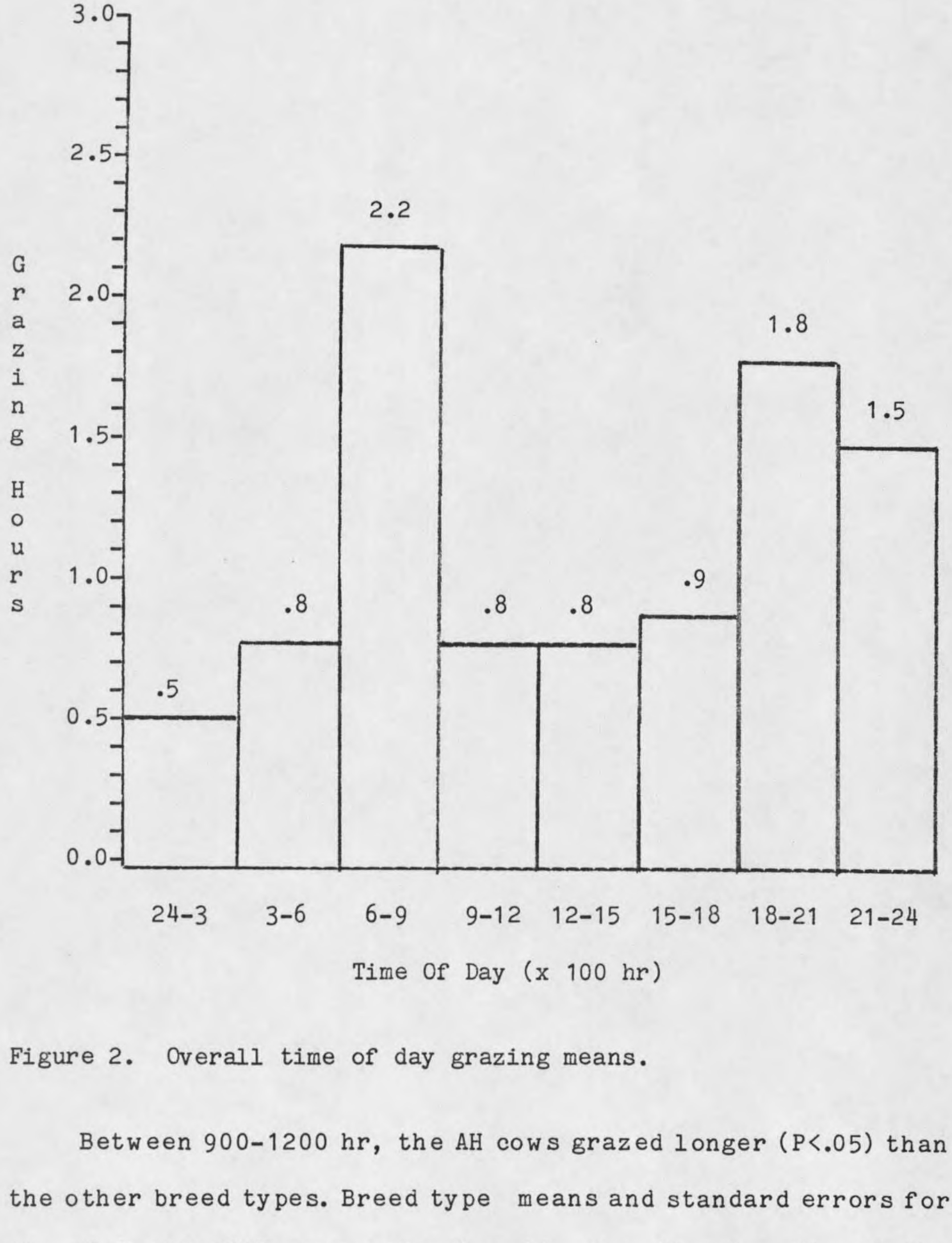

Figure 2. Overall time of day grazing means.

Between 900-1200 hr, the AH cows grazed longer ($P<.05$) than all the other breed types. Breed type means and standard errors for HH, AH, 1S1H and 3S1H cows were .8 ± .05, .9 ± .05, .7 ± .05 and .8 ± .05 hr, respectively. Because there was no significant breed type x period(group) interaction during this time period, this relationship held true during all four of the grazing periods. The longer grazing