CHARACTERIZATING LOW-QUALITY FORAGE UTILIZATION: FEED VALUE OF A SOLID STEM STRAW & EFFECTS OF AN ABRUPT SWITCH FROM CORN-CONTAINING TO FORAGE-ONLY DIETS

by

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ABSTRACT

Two separate studies were conducted to characterize low-quality forage utilization. The objective of the first trial was to evaluate the suitability of common small grain straws as efficient roughage sources in livestock diets, specifically comparing a solid-stem winter wheat variety (Bynum) to hollow-stemmed varieties of winter wheat (Norris and Willow Creek) and a barley variety (Geraldine). This was a two-part trial involving an *in vitro* dry matter disappearance (IVDMD) experiment and an individual lamb feeding trial. The IVDMD kinetics trial was conducted using a Daisy Wheel™ incubator, with replicated straw samples removed after 0, 6, 12, 24 48 and 96 hours. In a feeding trial, 16 crossbred wether lambs were randomly assigned to one of four diets containing chopped straw. The solid-stem characteristic of Bynum did not affect the feeding value of the straw compared with barley straw and other winter wheat varieties.

The objective of the second trial was to characterize how quickly the rumen adapts to a forage-only diet after an abrupt switch from a concentrate-containing diet. Twelve ruminally-cannulated Hereford-cross heifers were randomly assigned to 3 individually-fed, pre-experiment diets (4 heifers/diet). Diets were: 1) all forage, 2) 35% concentrate, and 3) 70% concentrate. Heifers were fed the diets for ~100 d before the start of the trial. Pre-experiment diets consisted of grass-alfalfa hay, corn, and soybean meal-urea supplement added to make the diets isonitrogenous at 13% CP. On d 0, diets were abruptly switched to grass hay. In situ digestibility runs were conducted starting on d -8 and ran continuously (d 1, 4, 7, 10, 13, 16, 19, 22) after the diet switch. Duplicate sample bags filled with 5 g of grass hay and a blank bag were incubated for 0, 24, 48, and 96 h. Organic matter and NDF digestibilities in subsequent in situ runs were similar ($P > 0.10$), regardless of pre-experiment diet. Rate of digestion was not influenced by pre-experiment diet ($P = 0.74$; avg 4.3 ± 0.002%/h). Forage digestibility was depressed when heifers were fed a high-concentrate diet; however, this effect disappeared within 48 h of feeding 100% forage.

CHAPTER 1, UTILIZATION OF COMMON CEREAL STRAWS BY LIVESTOCK

Literature Review

Small cereal grains are an important component of Montana agriculture. With over 2.5 million acres of winter wheat and approximately 900,000 acres of barley planted in 2009, straw from those crops is readily available to livestock producers (NASS-USDA, 2010). Wheat and barley straw can be used as supplemental roughage to extend hay supplies. However, nutritive quality of these straws can be a concern. Cereal straws are generally less digestible, as well as contain less protein and energy than higher quality forages such as alfalfa.

White et al. (1981) tested the digestibilities of winter wheat, spring wheat, barley, and oat cultivars grown in Montana. In vitro dry matter digestibility of winter wheat ranged from 30 to 46% over a two year test period. Differences in straw digestibilities of several spring wheat cultivars indicate that producers can use selection to improve digestibility. Barley straw had the highest digestibilities with a range of 33 to 52% over the two years. This research concluded that straw cultivars with higher digestibilities could be selected for without adversely affecting grain yield or other agronomic traits. In comparison, Johnson et al. (1962) reported in vitro digestibility of cellulose in alfalfa and several grasses. Three different alfalfa clippings; pre-bud (early), pre-bud (late), and partial bloom, had digestibility coefficients of 60, 54, and 51, respectively. The grasses sampled were orchard, brome, reed canary, and timothy. Grasses were clipped at both the boot and bloom stage. Digestibility coefficients for grasses in the boot stage ranged from 72 to 83; and in the bloom stage, 51-66.

Due to reduced digestibilities and minimal amounts of crude protein of cereal grain straw, ruminants may not be able to consume enough to meet their nutritional requirements. Many experiments feeding straw use protein supplementation to provide adequate nutrition. As a result of supplementation, forage digestion and passage rate are improved, and intake increases as well. Protein supplements vary in type from alfalfa to soybean meal to non-protein nitrogen sources such as urea (Church and Santos, 1981; Males et al., 1982; Weder et al., 1999). In the study by Church and Santos (1981), cattle fed wheat straw were supplemented with either soybean meal or a molasses-based liquid supplement containing urea and ammonium polyphosphate as non-protein N sources. These workers found the greatest improvement of DM digestibility when CP was included at 1 g/kg $BW^{.75}$ regardless of source. They also reported that straw intake was more variable in heifers supplemented with the liquid supplement rather than soybean meal. Wiedmeier et al. (1983) fed Hereford steers 81.5% wheat straw with various amounts of soybean meal and corn starch to provide crude protein at 11, 9.5, 8, and 6.5%. Dry matter, cellulose, and hemicellulose digestibilities linearly increased as the level of dietary crude protein increased.

The use of supplements allows producers to feed straw for various reasons. Straw can be included in maintenance diets, growing diets, and winter rations. Lesoing et al. (1981) conducted 3 growth trials feeding steers either untreated wheat straw or 4% NaOH-treated wheat straw. They found that with the addition of minerals, cattle fed alkaline treated straw at 50% of the diet were 14.7% more efficient than steers receiving untreated straw. Steers fed barley straw and alfalfa had lower rates of gain, reduced

intake, and lower dressing percentages than steers fed a concentrate mixture of ground barley, dried molasses beet pulp, and cottonseed meal (Lofgreen and Christensen, 1962). Wheat straw was included in winter rations for dry, pregnant beef cows in two separate experiments (Males et al., 1982). In trial 1, treatments were 1) 100% alfalfa hay; 2) 67% alfalfa hay, 33% wheat straw; 3) 33% alfalfa hay, 67% wheat straw; and 4) 75% Wheat straw + 25% barley-urea supplement. Treatments for trial 2 were 1) 67% brome grass hay, 33% wheat straw; 2) 87% wheat straw + 13% soybean meal-urea supplement; 3) 33% brome grass hay, 67% wheat straw; and 4) 75% wheat straw + 25% barley-urea supplement. There was no difference in days to first estrus among treatments in trial 1. Although, cows fed treatment 2 had higher conception rates compared to cows fed the high straw diets. In trial 2, cows receiving diet 4 (highest energy content) had a shorter post-partum interval. There were no significant differences in conception rates in trial 2; however, cows with higher energy and protein intakes tended to have greater pregnancy rates (Males et al., 1982). The inclusion of wheat straw in winter diets for cattle can be advantageous as long as both protein and energy requirements are met.

There is limited data concerning the specific wheat varieties used in this study other than the cultivar registrations. 'Willow Creek' forage winter wheat is a tall, late-maturing variety that was developed at Montana State University and released in 2005. Due to its later maturity, Willow Creek has forage characteristics appropriate for use in maintenance diets for livestock (Cash et al., 2009). Willow Creek wheat hay fed to calves in a backgrounding trial was found to be an acceptable forage source similar to barley or oat hay (Todd et al., 2007). 'Bynum' is a hard red winter wheat variety that

was developed by the Montana Agricultural Experiment Station. This is a solid-stem cultivar that shows tolerance to wheat stem sawfly (Carlson et al., 2007). Other cultivars used for comparison in this experiment were hollow-stem 2-row malt barley (Geraldine) and hard-red winter wheat (Norris) varieties. There are concerns whether solid-stem wheat varieties will degrade as quickly as hollow-stem varieties if left in the field (S. D. Cash, MSU, Bozeman, MT, personal communication). However, there is a lack of information about degradation characteristics of solid-stem cultivars to address this issue.

Straw from cereal grains can be included as an efficient roughage source in livestock diets when hay supplies are limited. However, straw quality should be determined in order to know if protein and energy requirements are met or if further supplementation is needed. Of particular interest in this study was the evaluation of a solid-stem wheat cultivar which provides some physical tolerance to the wheat stem sawfly compared to conventional hollow-stem cultivars. The objective of this trial was to compare feeding value of cultivars of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) in livestock diets using in vitro digestibilities and an individual lamb feeding trial.

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CHAPTER 2, IN SITU DIGESTIBILITY OF GRASS HAY AFTER HEIFER DIETS ARE ABRUPTLY CHANGED FROM 35 OR 70% CONCENTRATE TO 100% FORAGE

Literature Review

Little is known about the changes that may occur when ruminants are abruptly switched from a concentrate-containing diet to one of all forage. This situation might be common where heifers or bulls are developed in confinement, and then turned out to pasture for the breeding season. Beck et al. (2003) found that steers limit-fed high concentrate diets were able to adapt to pasture as well as steers fed hay-based diets. Conversely, Tolley et al. (1988) reported that steers and heifers lost weight in the first 2 wk after being switched from a high energy diet to a low energy diet. This chapter will summarize various effects diets have on metabolic functions such as forage digestibility, ruminal ammonia, rumen pH, volatile fatty acids, and blood metabolites.

Digestibility

Forage digestibility was important in this research to determine when the rumen adapted to an all forage diet from concentrate containing diets. Therefore, this section will focus on the effects of cereal grain on forage digestibility. Many experiments have focused on cereal grain supplementation and its associated effects on forage digestion. Chase and Hibberd (1987) provided cows maintained on low-quality hay (4.2% CP, 52.5% ADF), with 0, 1, 2, or 3 kg/d of supplemental ground corn along with cottonseed meal to maintain protein intake. They reported a linear decrease in hemicellulose and cellulose digestibility as ground corn level increased. Steers grazing summer pasture

(12.8% CP, 47.4% ADF) receiving whole corn at 0.2% BW had higher OM disappearance than steers fed corn at 0.4 and 0.6% BW (Pordomingo et al., 1991). Also in that study, IVOMD of esophageal masticate was not affected by corn, meaning inoculum from steers fed different levels of corn were similar. Kartchner (1981) supplemented cows on winter range with cracked barley (energy) and either cottonseed meal one year or soybean meal the following year. In year 1, there was no difference in forage DM digestibility between treatments. In year 2, forage DM digestibility was lower ($P < 0.01$) for the cracked barley group than the soybean meal or control group.

Cellulose is broken down by four main microbial species: *Bacteroides succinogenes, Ruminococcus flavefaciens, R. albus,* and *Butyrivibrio fibrisolvens* (Yokoyama and Johnson, 1993). These bacteria are most abundant when high roughage diets are fed. Feeding high concentrate diets reduces rumen pH below 6, which in turn affects cellulolytic bacteria (Yokoyama and Johnson, 1993). A low pH may affect bacteria in various manners. Microbial attachment to cellulose may be inhibited due to lower levels of bicarbonate or increased levels of soluble starch. Cell division and growth might also be negatively affected by a low pH, reducing the population of cellulolytic bacteria (Owens and Goertsch, 1993). These factors may partially explain why reduced rumen pH caused by fermentation of readily available carbohydrates decreases digestibility of cellulose. Another cause of depressed digestibility is low ruminal ammonia concentrations. Rumen microbes require N sources for efficiency; without adequate ammonia levels, rate of digestion decreases resulting in decreased feed

intake (Owens and Zinn, 1993). Satter and Slyter (1974) suggest a maximal level of ruminal ammonia concentration of 5 mg/dL to optimize microbial efficiency.

Ruminal Ammonia

This section of the review will focus on ruminal ammonia and how nitrogen levels in the rumen may affect fiber digestion. Ruminal ammonia is obtained from breaking down dietary protein and NPN, from hydrolysis of recycled urea, and from degradation of microbial protein. Ammonia leaves the rumen by utilization by microbes, absorption through the rumen wall, and flowing to the omasum (Owens and Zinn, 1993). Satter and Slyter (1974) reported a minimum ruminal ammonia level at 5 mg/dL before microbial efficiency is affected, therefore depressing fiber digestion. In a study by Adams et al. (1987), steers grazing pastures containing western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), needle-and-thread grass (*Stipa comata*), and threadleaf sedge (*Carex filifolia*) in September and October, had ammonia concentrations near the level where fiber digestion is negatively affected. Although, they stated rumen ammonia levels were diluted due to greater rumen volume in September and October. Park et al. (1994) found greater levels of ruminal NH_3 concentrations in steers grazing wheatgrass pastures in May and June than in September or November. This agrees with others who have reported decreases in ruminal NH_3 as plants mature and N content deceases.

Chase and Hibberd (1987) reported a peak of ruminal NH_4 at 3 h after feeding ground corn to steers before rapidly declining. In an experiment by Wheeler et al. (1979) steers (BW 242 kg) received low-quality roughages at 2% of body weight such as orchard

grass (10.1% CP, 40.7% ADF), barley straw (4.2% CP, 57.0% ADF), corn stover (4.1% CP, 58.6% ADF), and cottonseed hulls (6.6% CP, 70.2% ADF). A supplement containing 90% soybean meal and 10% minerals was also fed. Steers fed orchard grass, barley straw, and corn stover had similar ruminal ammonia levels: 19.6, 15.7, and 24.1 mg/dL, respectively. However, cottonseed hulls had a lower ammonia level (4.4 mg/dL) than the other treatments. This could be explained by the higher intake level of cottonseed hulls resulting in a quicker rate of passage and reduced microbial degradation.

Rumen pH

Rumen pH is another factor that affects forage digestibility and therefore important this research. Cattle being fed a roughage diet will have a rumen pH range from 6.2 to 7. Concentrate diets fed to cattle will decrease the pH range from 5.5 to 6.5 (Owens and Goetsch, 1993). This can occur when low-quality forages are supplemented with cereal grains such as corn or barley. When rumen pH falls below 6, cellulose digestion is negatively affected (Owens and Goetsch, 1993). Cows fed 3 kg/d of supplemental ground corn along with cottonseed meal had depressed ruminal pH levels 6 hours after feeding, but pH was not below the minimum level to depress cellulolytic activity (Chase and Hibberd, 1987). Pordomingo et al. (1991) reported supplemental whole corn did not affect ruminal pH while steers were grazing blue grama rangeland during summer months. Steers grazing wheatgrass from April until December had a range of ruminal pH from 5.9 to 6.2 which is below the level considered optimal for fiber digestion (Park et al., 1994). Likewise, Adams et al. (1987) reported a rumen pH range from 5.9 to 6.6 for steers grazing native rangeland with mainly western wheatgrass from

May until October. In both trials, steers received no supplement and effects of forage maturity on rumen fermentation were examined. Adams et al. (1987) suggested that ruminal pH and ammonia levels in September and October may have limited optimal forage digestion. This issue could be solved by adding supplemental protein during these months. Park et al. (1994) also recommended supplemental protein late in the grazing season to improve upon low forage nitrogen and increase animal performance.

Volatile Fatty Acids

Rumen microbes degrade carbohydrates into pyruvate which can be further broken down to three major volatile fatty acids (VFA) which are acetate, propionate, and butyrate as well as other VFAs. These VFAs provide 50-85% of metabolizable energy to the ruminant when being fed a forage diet (Owens and Goetsch, 1993). Figure (2.1) diagrams the process of ruminal fermentation of carbohydrates to pyruvate in the rumen. Acetic acid is a pre-cursor for fatty acid synthesis or is oxidized by the tricarboxylic acid (TCA) cycle and used for energy (Fahey and Berger, 1993). Ruminants receiving roughage diets will have a greater proportion of acetate compared to propionate and butyrate. Propionate is a pre-cursor for glucose synthesis and increases when ruminants are fed grain diets. Butyrate is absorbed through the rumen wall and is converted to ketones. The process of converting pyruvate to volatile fatty acids via the liver is shown in Figure (2.2). Pordomingo et al. (1991) reported supplemental corn did not affect total VFA concentrations. Chase and Hibberd (1987) also found no influence of treatment on total VFA production. As supplemental corn increased, acetic acid decreased linearly while butyric acid increased linearly.

Blood Metabolites

Grain diets produce a higher proportion of propionic acid compared to acetic and butyric acid (Lyle et al., 1981). Since propionate is a precursor to glucose, high grain diets will have a greater amount of blood glucose compared to high forage diets (Fahey and Berger, 1993). Insulin is produced by the pancreas in response to glucose, amino acids, hormones, and drugs. Insulin binds to its receptors on cell plasma membranes and activates glucose transporters (GLUT-4) which aid in allowing glucose into cells (Kaneko et al., 1997). Two important functions of insulin are to encourage glucose transfer into muscle and fat cells and glucose utilization (Kaneko et al., 1997).

Stimulation of protein catabolism can increase blood urea nitrogen (BUN) level (Kaneko et al., 1997). Examples of increased BUN concentrations include consuming a high protein meal; a fever, which increases tissue catabolism; infections; starvation; and drugs. Conversely, anabolic steroids, reduced protein intake, and severe hepatic insufficiency will decrease BUN levels (Kaneko et al., 1997). Feeding carbohydrates in excess of requirements will increase fat deposits in the body as well as fatty acid (FA) levels in the blood. Fasting will also elevate FA in blood as the body is using fat stores as an energy source. Normal serum glucose levels in cattle fall in a range of 45-75 mg/dL and urea nitrogen: 20-30 mg/dL (Kaneko et al., 1997). Brickner et al. (2007) reported a basal NEFA concentration of 84 µmol/L in non-lactating and non-gestating Holstein cows while determining the effect of sampling protocol on NEFA levels. McAtee and Trenkle (1971) reported a basal insulin concentration in 5 month-old heifers of 0.5 ng/mL. Similarly, León et al. (2004) found insulin levels of 0.4 - 0.5 ng/mL in heifers

with a body condition score (BCS) of 4-5 and >0.6 ng/mL in heifers with a BCS of 6 while determining endocrine changes in heifers with condition score changes.

A study conducted with lactating dairy cows fed various levels of high-quality alfalfa silage (avg CP 20.6%, avg ADF 35.8%) found a decrease in blood glucose as the proportion of forage increased (Dhiman et al., 1991). However, blood urea N concentrations were not affected by increasing forage percentages. Dhiman et al. (1991) also found no response in plasma free fatty acids as alfalfa silage concentrations increased. Park et al. (1994) reported higher serum glucose concentrations in steers grazing intermediate wheatgrass in May than in June, September, and November. They also found greater serum urea N in May and June compared to September and November. In addition, Park et al. (1994) reported increased non-esterified fatty acid concentrations with increasing plant maturity. They found higher insulin levels in June (0.63) than in May (0.47), September (0.50), and November (0.37). Crude protein and ADF content of wheatgrass for May, June, September, and November was 15.0, 42.2; 14.9, 43.7; 7.4, 51.8; and 5.75, 59.7% respectively (Park et al., 1994).

Although situations when ruminants are switched from concentrate-containing diets to an all-forage diet are fairly common (i.e. heifers or bulls developed in confinement and then turned out to pasture during the breeding season), not much is known about the effect this switch has on the rumen environment. This review described metabolic function as it is affected by various concentrate and roughage diets, in an attempt to understand the physiological changes occurring in the rumen during a diet change.

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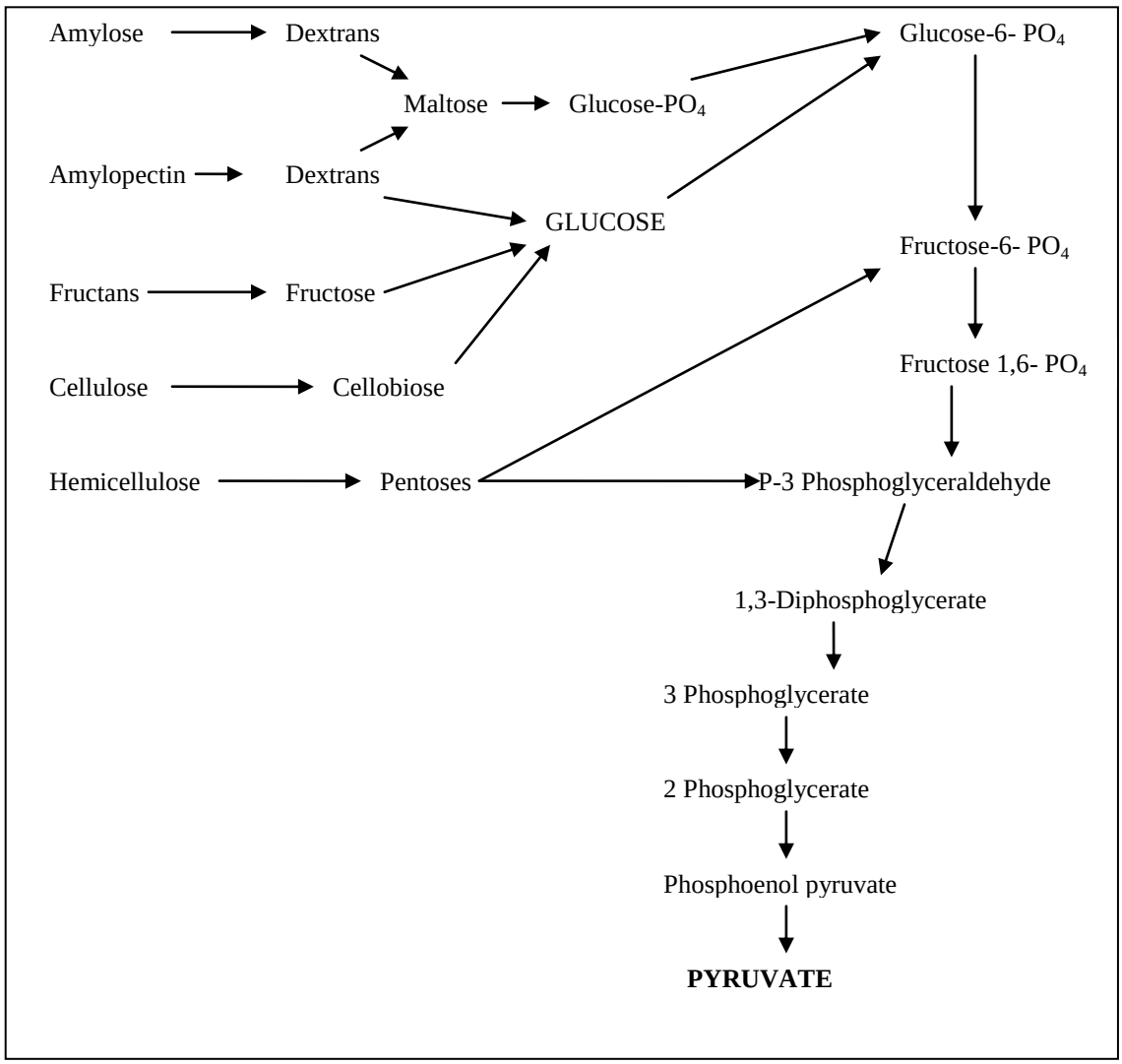


Figure 2.1. Ruminal fermentation of carbohydrates to pyruvate.

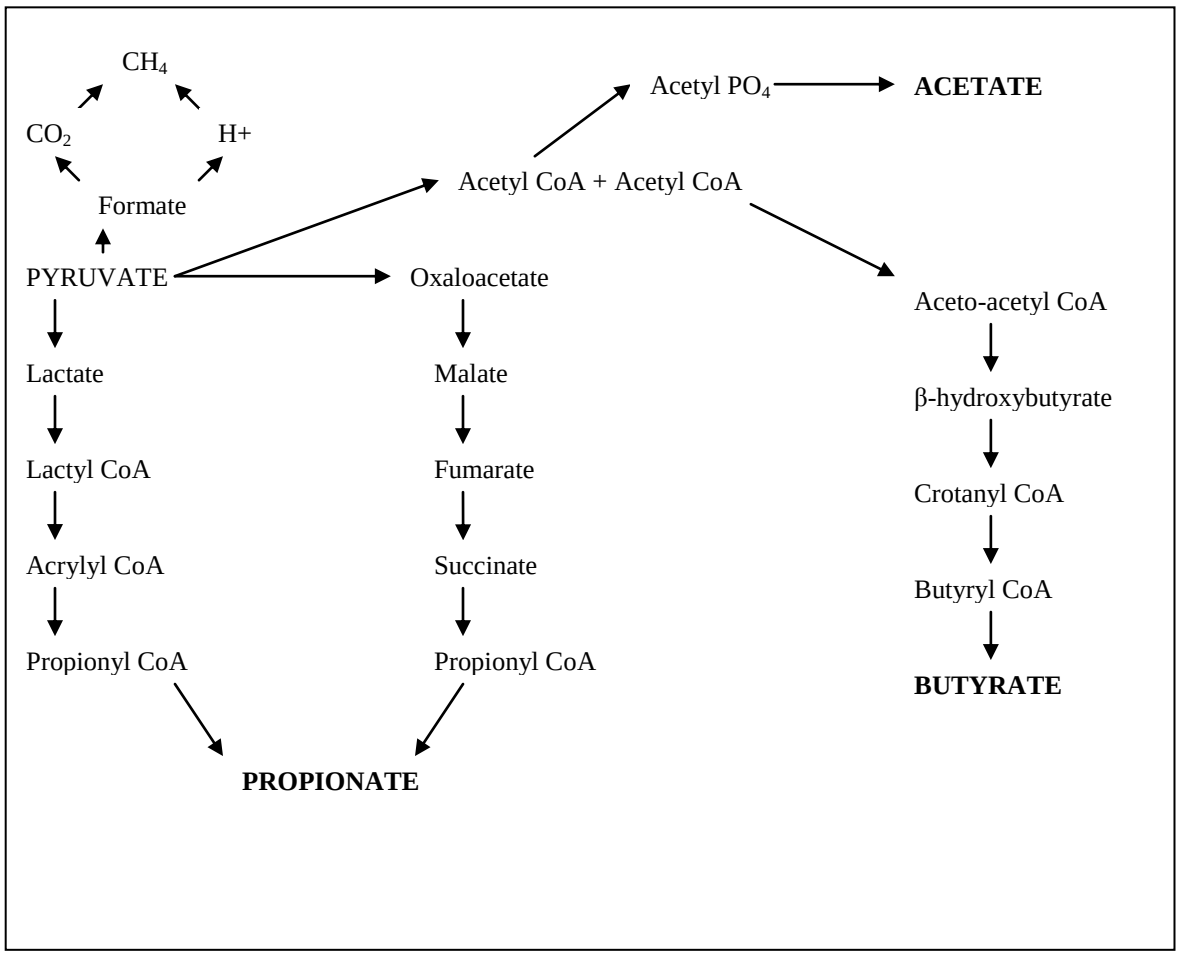


Figure 2.2. Ruminal fermentation of pyruvate to volatile fatty acids.

CHAPTER 3, UTILIZATION OF COMMON CEREAL STRAWS BY LIVESTOCK

Introduction

Cereal crop residue is a valuable roughage resource for livestock producers. Of particular interest in this study was the evaluation of a solid-stem wheat cultivar which provides some physical tolerance to the wheat stem sawfly compared to conventional hollow-stem cultivars. The objective of this trial was to compare feeding value of cultivars of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) in livestock diets using in vitro digestibilities and an individual lamb feeding trial.

Materials and Methods

In Vitro Dry Matter Disappearance Experiment

The experiment was conducted at the Montana State University's Nutrition Center. Experimental procedures were approved by the institute's Animal Care and Use Committee. All grain varieties were grown and baled in Gallatin County, MT during the summer of 2008. Grain varieties included: 1) Willow Creek forage winter wheat, 2) Bynum winter wheat, 3) Norris winter wheat, and 4) Geraldine 2-row malt barley (Table 3.1).

Table 3.1. Nutrient composition of straw cultivars[1].

	Treatments			
Item (%)	BAR	WC	NOR	BYN
DM	84.38	87.08	84.71	85.89
CP	8.37	5.42	4.76	4.62
ADF	33.40	48.20	44.90	43.50
TDN	48.50	34.40	35.80	38.60
NEm	0.47	0.30	0.32	0.35

[1] Treatments included Geraldine malt barley (BAR), Willow Creek winter wheat (WC), Norris winter wheat (NOR), and Bynum solid-stem winter wheat (BYN).

In order to obtain a uniform set of straw samples, standardize the in vitro test, and reduce sampling error, stems and nodes were sampled excluding leaf blades and grain heads. The internode length was measured for 10 stems of each variety, the average length was calculated, and then divided in half. This length was measured and clipped each side of a node. Clipped samples were ground to pass a 1-mm screen using a Wiley Mill.

Triplicate F57 filter bags (Ankom Technology Corp., Fairport, NY) filled with 0.5 g of straw were placed in a Daisy Wheel™ jar (1 jar/straw variety). Rumen inoculum was collected, approximately 2 hours after feeding, from cows fed an ad libitum diet of winter wheat forage hay for 5 days. In vitro dry matter digestibility of each straw variety was determined using a Daisy^{II} incubator over a 96 h period using the In Vitro True Digestibility method described by Ankom (Ankom Technology Corp., Fairport, NY). Bags were inserted in the jars as a group and incubated for 0, 6, 12, 24, 48, and 96 h. Once removed from the jars, bags were rinsed under cold tap water until effluent was clear. Rinsed bags were oven dried and stored at -20° C until analyzed for NDF and ADF. Rate of digestion (%/h) was calculated from the dry in vitro bags using the following equation.

$$\text{Rate of digestion} = \frac{\text{Ln}\,[100 - (\%\ \text{digested}/\%\ \text{potential} \times 100)]}{\text{Incubation time}}$$

Individual Lamb Trial

The experiment was conducted at the Montana State University's Nutrition Center. All experimental procedures were approved by the institute's Animal Care and Use Committee.

Sixteen crossbred wether lambs (6 mos, 38 ± 3 kg) were used in a completely randomized design to evaluate straw from common small cereal grains. Lambs were assigned to 1 of 4 isocaloric (~60% TDN) diets containing chopped straw: 1) Willow Creek forage winter wheat, 2) Bynum winter wheat, 3) Norris winter wheat, and 4) Geraldine 2-row malt barley (Table 3.2). Chopped grass hay, corn, and soybean meal were included to provide similar amounts of DIP (103-114% of their requirement; NRC, 2007). One hundred grams of a molasses-water mix (50:50) was added to reduce dust and improve intake of the ground straw.

Table 3.2. Cereal straw diets[1] fed to wethers.

	Treatments			
Ingredient (%)	BAR	WC	NOR	BYN
Straw	59.67	44.89	45.78	45.78
Soybean meal	13.67	10.73	10.95	10.95
Grass hay	26.11	20.49	20.9	20.90
Corn		23.42	21.89	21.89
Mineral	0.55	0.47	0.48	0.48
Molasses	0.10	0.10	0.10	0.10

[1] Treatments included Geraldine malt barley (BAR), Willow Creek winter wheat (WC), Norris winter wheat (NOR), and Bynum solid-stem winter wheat (BYN).

Wethers were housed in metabolism crates (75 cm × 125 cm) in a temperature-controlled room and adapted to the treatments for 10 d before a collection period of 7 d. Wethers were fed 1,000 g/d to reduce the amount of refusals. If a wether left no refusals for 2 consecutive days, then rations were increased to 1,100 g/d. Water was available at all times. On d 10, wethers were fit with fecal collection bags. Total fecal collection did not start until d 11. On d 11 to 17, total feces were collected at the same time as feeding at 0700 h. Fecal samples, composited for each animal, were weighed on d 17, mixed in a Hobarth mixer, and an approximate 200 g subsample was collected. Feed ingredients were sampled at the end of the trial. Refusals were weighed daily and composited for each lamb.

Feed ingredients, fecal samples, and refusals were dried at 55°C for 48 h. Dried samples were ground in a Wiley mill to pass through a 1-mm screen. Feed and fecal samples were analyzed for DM, ash, (AOAC, 1990), NDF, ADF (Goering and Van Soest, 1970), and nitrogen (Leco FP 528 nitrogen analyzer). The following equation demonstrates how OM digestibility was calculated; NDF and CP digestibilities were calculated similarly.

$$\text{OMD} = \frac{\text{OM intake} - \text{OM fecal output}}{\text{OM intake}} \times 100$$

Results were analyzed as a completely randomized design (Statistics 9.0, 2008) with wether as the experimental unit. Means were separated by the LSD procedure and differences were considered significant at the $P < 0.05$ level.

Results and Discussion

In Vitro Experiment

Straw variety influenced rate of digestion ($P = 0.03$, Figure 3.1). The solid-stem winter wheat, Bynum, had a digestion rate similar to barley and Willow Creek ($P \geq 0.18$). Bynum and Barley both had higher rates of digestion (-4.30 and -4.28%/h, respectively) than Norris (-3.82%/h) and Willow Creek forage wheat (-4.08%/h) had an intermediate rate of digestion. Wheeler et al. (1979) found a similar in vitro digestion rate (4.29%/h) for barley straw. A possible explanation for a lower digestion rate for hollow-stemmed straw varieties (Norris, Willow Creek, Geraldine Malt Barley) might be they contain more lignin than solid-stem varieties (Bynum, Genou, or Rampart) in order to prevent lodging which can occur if the stem is not strong enough to support the plant.

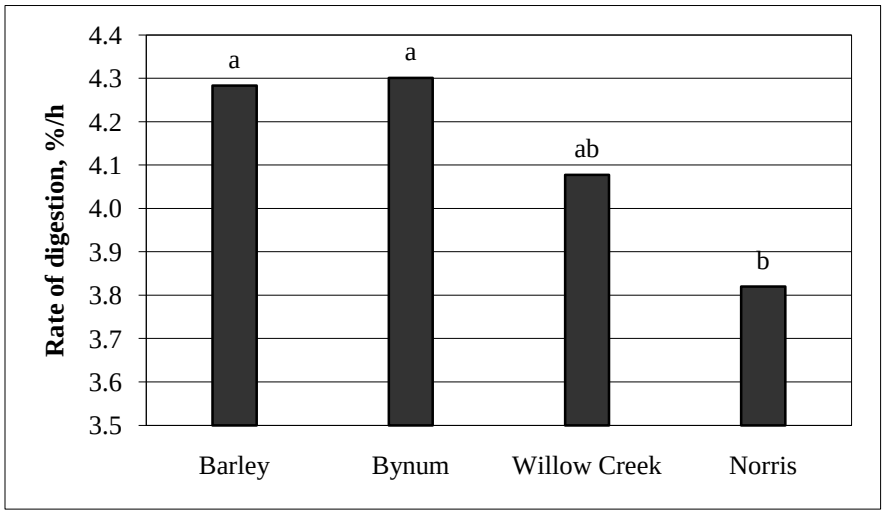


Figure 3.1. Rates of digestion (%/h) of various small grain cereal straw cultivars.
[ab] Means with different superscripts within row differ ($P = 0.01$, SE = 0.10).

Feeding Trial

In addition to the in vitro experiment, mixed rations including the straw varieties were fed to wethers in metabolism crates. The Bynum-containing diet (66.7%) had a greater ($P < 0.05$) OM digestibility than the Willow Creek diet (63.6%) and both were greater than the Norris (60.6%) and Barley diets (60.5%; Figure 3.2). These results suggest that the solid-stem characteristic of Bynum is not detrimental to forage quality. Barley, Bynum, and Willow Creek diets all had higher ($P < 0.05$) CP digestibilities than the Norris-containing diet (Figure 3.3). Neutral detergent fiber digestibility of the Barley diet was greater ($P < 0.05$) than the other three treatments which did not differ from one another (Figure 3.4).

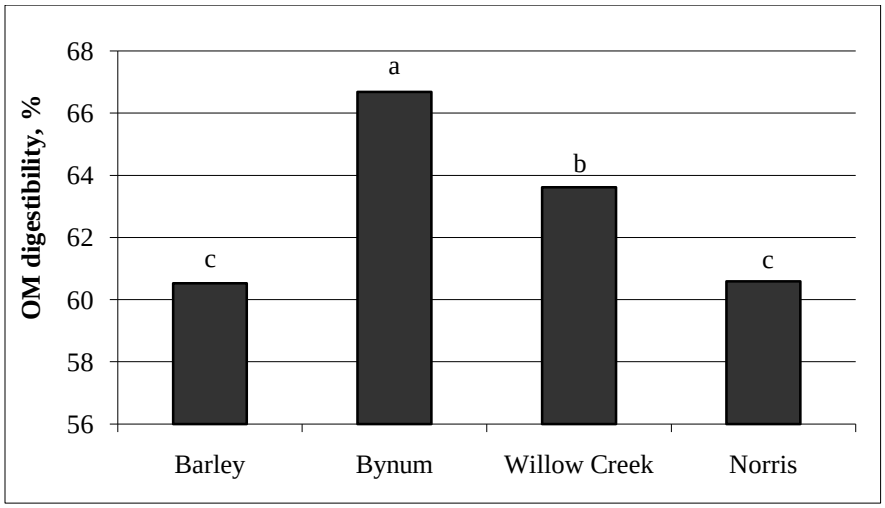


Figure 3.2. Effect of straw variety on diet OM digestibility.
[abc] Means with different superscripts within row differ ($P < 0.05$).

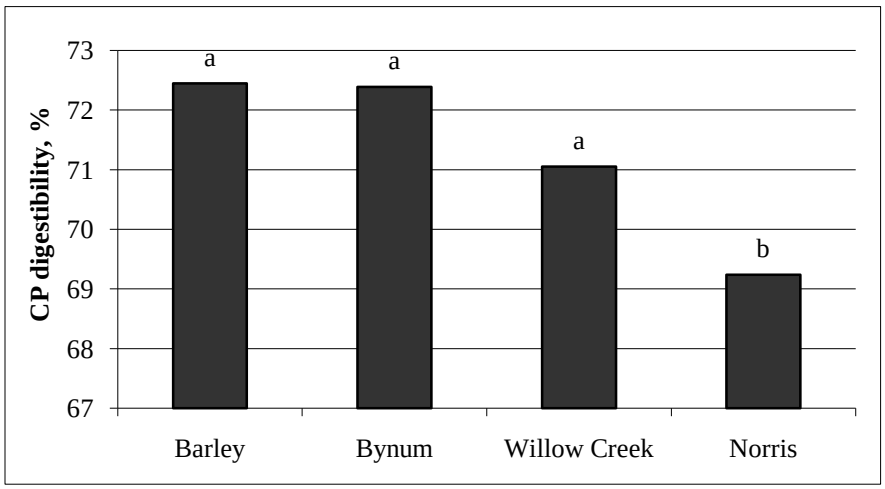


Figure 3.3. Effect of straw variety on diet CP digestibility.
[ab] Means with different superscripts within row differ ($P < 0.05$).

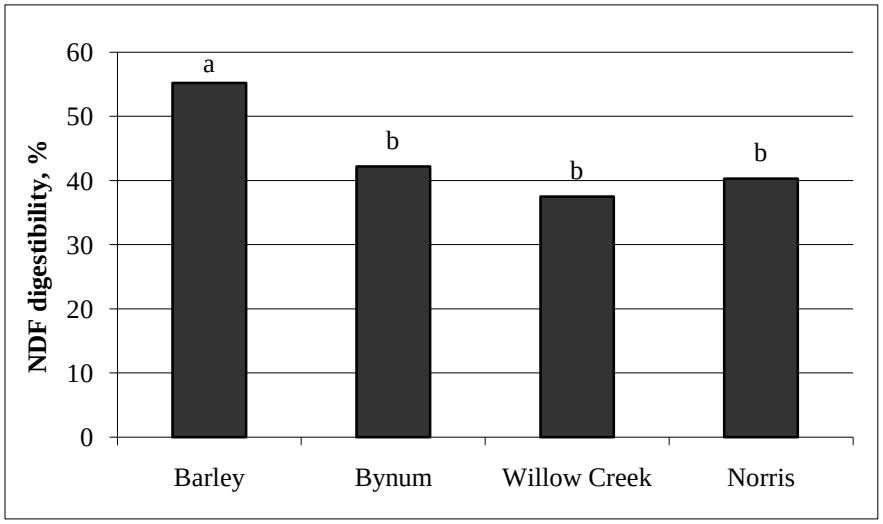


Figure 3.4. Effect of straw variety on diet NDF digestibility.
[ab] Means with different superscripts within row differ ($P < 0.05$).

Calculated digestibilities were based on the whole diet, while the rates were calculated using the straw varieties alone. White et al. (1981) reported 48 h in vitro digestibilities for various winter wheat varieties ranging from 30 to 46% over a two-year test period. Barley straw was reported as having the highest digestibilities with a range of 33 to 52% over the same two years. While studying the effects of fat sources on wheat

straw diets fed to steers, Moore et al. (1986) reported an OM digestibility of 58.3% for a complete ration containing 68.9% wheat straw. In a related study, OM digestibility was reported as 59.9% for a ration containing 75.7% straw (Moore et al., 1986). Coombe et al. (1979) found OM digestibility of 57% for a chopped barley straw ration. The higher digestibilities reported in the lamb feeding trial might be due to the more digestible ingredients such as grass hay, soybean meal, and corn.

Conclusion

Producers can include cereal straws in livestock diets as an efficient roughage source as long as protein or energy is supplemented as needed to meet the animals' requirements. The solid-stem characteristic of Bynum winter wheat did not affect the feeding value of the straw compared with barley straw and other winter wheat varieties.

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CHAPTER 4, IN SITU DIGESTIBILITY OF GRASS HAY AFTER HEIFER DIETS ARE ABRUPTLY CHANGED FROM 35 OR 70% CONCENTRATE TO 100% FORAGE

Introduction

Few studies have examined the changes that may occur when ruminants are abruptly switched from a concentrate-containing diet to one of all forage. This situation might be common where heifers or bulls are developed in confinement, and then turned out to pasture for the breeding season. Beck et al. (2003) found that steers limit-fed high concentrate diets were able to adapt to tall-fescue pasture as well as steers fed hay-based diets. Conversely, Tolley et al. (1988) reported that steers and heifers lost weight in the first 2 wk after being switched from a high energy diet to a low energy diet. On the other hand, there is an abundance of literature pertaining to changing cattle diets from forage to concentrates. Lyle et al. (1981) summarized that cattle consuming high grain diets with monensin added have lower ruminal pH levels, higher total VFA concentrations, and higher propionate levels compared to acetate and butyrate. Also, the effects of cereal grain supplementation are widely known. Chase and Hibberd (1987) reported that as supplemental ground corn increased, there was a linear decrease in digestibility of cellulose and hemicellulose in low quality grass hay. On the other hand, corn did not affect OM digestibility in steers grazing summer pastures (Pordomingo et al., 1991). Kartchner (1981) found no significant effects on DM digestibility when cows grazing winter range were fed supplemental energy (cracked barley).

Therefore, the objective for the present experiment was to characterize ruminal function in heifers after an abrupt diet switch from diets containing 35 or 70% corn to a diet containing forage only compared to animals that were maintained on a forage diet alone.

Material and Methods

Procedures were approved by the Fort Keogh Livestock and Range Research Laboratory Animal Care and Use Committee. Twelve ruminally-cannulated Hereford-cross heifers (non-pregnant, 2-yr-old, 508 ± 2 kg) were randomly assigned to one of three pre-experiment diets (4 heifers/diet). Pre-experiment diets were: 1) 100% forage (**CONTROL**); 2) 35% concentrate (**35%**); and 3) 70% concentrate (**70%**). The concentrate diets included grass/alfalfa hay, corn (9.8% CP) and urea. The 100% forage diet consisted of chopped grass and alfalfa hay (75% and 25% respectively). Soybean meal was added to the 70% diet to make the diets isonitrogenous at 13% CP. Melengesterol acetate (**MGA**), vitamins, and minerals were included in all the diets. Melengesterol acetate was fed at 0.23 kg · heifer^{-1} · d^{-1} in a pelleted form to deliver 0.5 mg · heifer^{-1} · d^{-1}. The purpose of feeding MGA to suppress estrus was to reduce variations in intake due to cyclicity. Heifers were individually fed at 0700 h for ~100 d before the trial began. On day 0, diets were immediately switched to chopped grass hay (6.2% CP) fed at 2% BW with MGA and a vitamin/mineral premix. Mineral supplement contained 34.0% salt, 19.1% dicalcium phosphate, 18.5% calcium carbonate, 8.8% dried distillers grain, 7.8% potassium chloride, 7.0% magnesium oxide, 2.0% trace mineral

premix, 1.5% mineral oil, 0.81% selenium, 0.32% copper sulfate, 0.21% manganese sulfate, and 0.04% vitamin A. Heifers had ad-libitum access to fresh water.

Dacron nylon bags (10 cm × 20 cm; pore size 53 ± 10 µm; Ankom Technology Corp., Fairport, NY) were used to test in situ grass hay digestion by the heifers before, during, and after the diet switch. In situ bags were also inserted 6 d before the diet switch in order to establish baseline digestibilities, as well as d 0, 3, 6, 9, 12, 15, 18, and 21. Beginning on d 0 at 0900 h, duplicate sample bags filled with 5 g of grass hay and 1 blank bag, to account for microbial attachment, were inserted into the ventral rumen sac and allowed to incubate for 24, 48, or 96 h. Nylon bags were placed in a 60 × 60-cm zippered mesh laundry bag and anchored with ~1 m of string attached to a rubber stopper. Bags were placed in the ventral sac of the rumen at specified intervals, removed simultaneously at the end of the incubation period, and immediately submersed in cold water to stop microbial fermentation. Bags were then rinsed under cold tap water until the effluent was clear. Rinsed bags were placed in a -20° C cooler until frozen after which they were freeze-dried for 72 h. Residue was removed from the nylon bag and analyzed for DM (AOAC, 1990), OM (AOAC, 1990), and NDF (Goering and Van Soest, 1970; ANKOM 200 fiber analyzer, ANKOM Technology, Fairport, NY). Grass hay was also analyzed for DM, OM, and NDF. Dry samples were ashed at 550° C in a muffle furnace for a minimum of 4 h. The following equation demonstrates how OM disappearance was calculated, and NDF disappearance was calculated similarly.

$$\text{OMD} = \frac{\text{OM sample weight} - (\text{OM residue weight} - \text{blank})}{\text{OM sample weight}} \times 100.$$

Rumen fluid samples were collected on the same days as the in situ runs at h -1, 2, 4, 8, 12, and 16 relative to feeding. Rumen liquid (40 mL) was strained through 4 layers of cheesecloth, a pH reading was taken, and the fluid was separated into 2 vials. One vial contained 2 mL of 6 *N* HCL and was later analyzed for ammonia (adapted from Broderick and Kang, 1980). The other vial contained no additive and was stored at -20° C until analysis for volatile fatty acids (VFA) using a Triplus GC (Thermo Fisher Scientific, Waltham, MA) equipped with a 15m × 0.53 mm (i.d.) × 1 um (d.f.) column (Stabilwax, Restek, Bellefonte, PA).

Blood (~10 mL) was collected at h -1, 4, and 8 relative to feeding on d -2, 0, 3, 6, 9, 12, 15, 18, and 21 via coccygeal venipuncture using serum separator tubes (Corvac, Sherwood Medical, St. Louis, MO). Tubes were spun at 1,500 × *g* for 30 min. Serum was decanted into duplicate tubes to be stored at -20° C. Serum metabolite concentrations were analyzed in duplicate by using commercially available kits to measure glucose via the glucose oxidase method (kit TR15321, Thermo DMA, Louisville, CO; intraassay CV of 2.4% and interassay CV of 3.8%), urea-N via the urease method (kit TR12321, Thermo DMA; intraassay CV of 4.1% and interassay CV of 4.8%), and NEFA [acyl-CoA synthetase-acyl-CoA oxidase (ACS-ACOD) method; cat. no. 994-75409, Wako Chemicals USA Inc., Richmond, VA; intraassay CV of 2.0% and interassay CV of 2.8%]. Serum insulin concentrations were measured in duplicate by solid-phase radioimmunoassay (Coat-A-Count kit, Siemens Medical Solutions, Deerfield, IL) using the method from Reimers et al. (1982). The insulin assay had an intraassay CV of 1.9% and an interassay CV of 7.6%, with 96% recovery.

In situ data were analyzed using the Mixed procedure of SAS (SAS Institute Inc., Cary, NC) with diet, run and diet × run interactions in the model. Run served as the repeated measure, with cow(diet) as the subject and compound symmetry as the covariance structure. Serum metabolite, rumen pH, ammonia, and VFA data were analyzed using the Mixed procedure of SAS with diet, sampling date, diet × sampling date, hour(sampling date), and diet × hour(sampling date) in the model. Cow(diet) served as the random effect. Hour(sampling date) was the repeated measure, with sampling date × cow(diet) serving as the subject. Compound symmetry was the covariance structure.

Results and Discussion

In Situ Digestibility

Results reported do not include 2 heifers (70%) that went off feed before the start of the trial. Pre-experiment diet × in situ run interactions occurred ($P \leq 0.04$) for OM and NDF digestibility. Organic matter digestibility of grass hay before the diet switch (d -2) was lower ($P \leq 0.10$) for 70% than for 35% or CONTROL; (Figure 4.1 and 4.2).

A comparable pattern was observed for NDF digestibility. After the diet switch (d 0), OM and NDF digestibility of grass hay in subsequent in situ runs were similar regardless of pre-experiment diet. Low digestibilities were observed for the high-concentrate containing diet during the baseline period, similar to results observed by Chase and Hibberd (1987). Beck et al. (2005) reported lower in situ DM digestibility of tall fescue in steers that were limit-fed high concentrate diets in drylot before being turned out for grazing. However, cows on the 70% concentrate diet were able to rapidly

adapt to the forage-only diet, as digestibilities were similar for all cows regardless of pre-experiment diet by 96 hours after the diet switch.

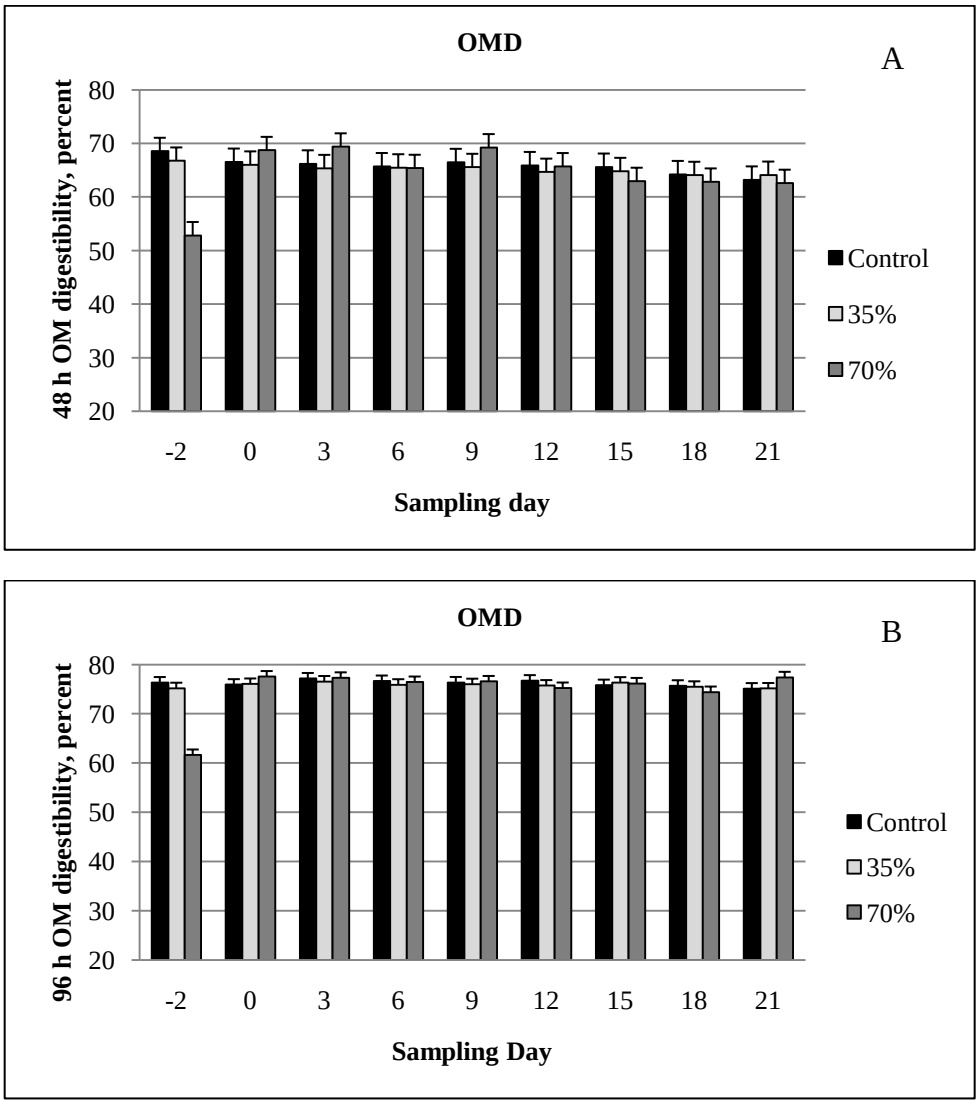


Figure 4.1. Pre-experiment diet × sampling day interaction ($P < 0.01$; SE = 2.5 and 1.1 for 48 and 96 h respectively) for A) 48- and B) 96-h in situ OM digestibilities. Cows were abruptly switched to an all forage diet on d 0.

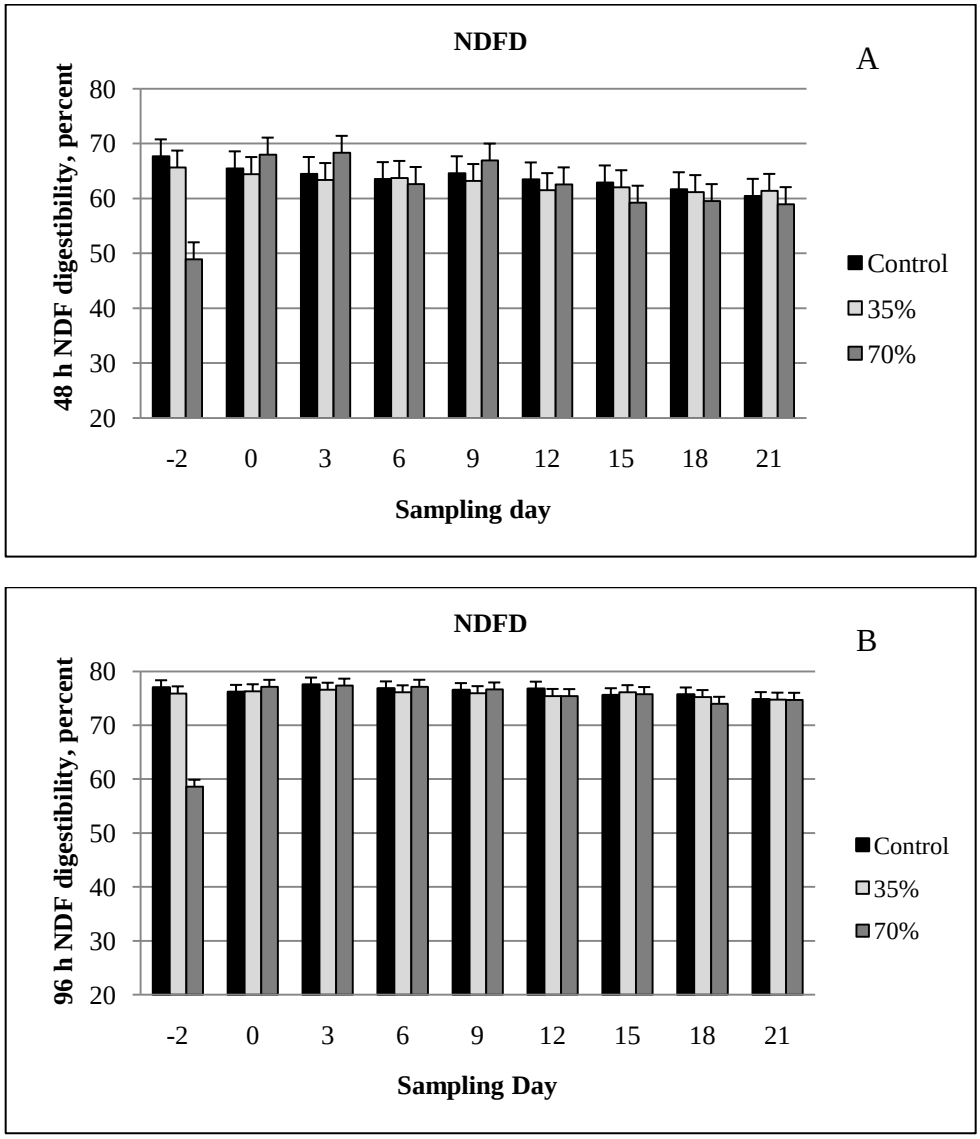


Figure 4.2. Pre-experiment diet × sampling day interaction ($P < 0.01$; SE = 3.1 and 1.3 for 48 and 96 h respectively) for A) 48- and B) 96-h in situ NDF digestibilities. Cows were abruptly switched to an all forage diet on d 0.

Rate of digestion was not influenced by pre-experiment diet ($P = 0.65$; avg 4.3 ± 0. 2%/h). Sampling day influenced rate of digestion ($P < 0.10$; Figure 4.3). Generally, rate of digestion decreased throughout the experiment except on d 9 when there was an increase. This increase could be due to seal failure on some of the bags during incubation in the rumen. Microbial efficiency is negatively affected when nitrogen is limited in the

rumen (Owens and Zinn, 1993). Due to the low-quality hay and the removal of higher nitrogen-containing ingredients after the diet switch, nitrogen may have been limiting the efficiency of the microbes.

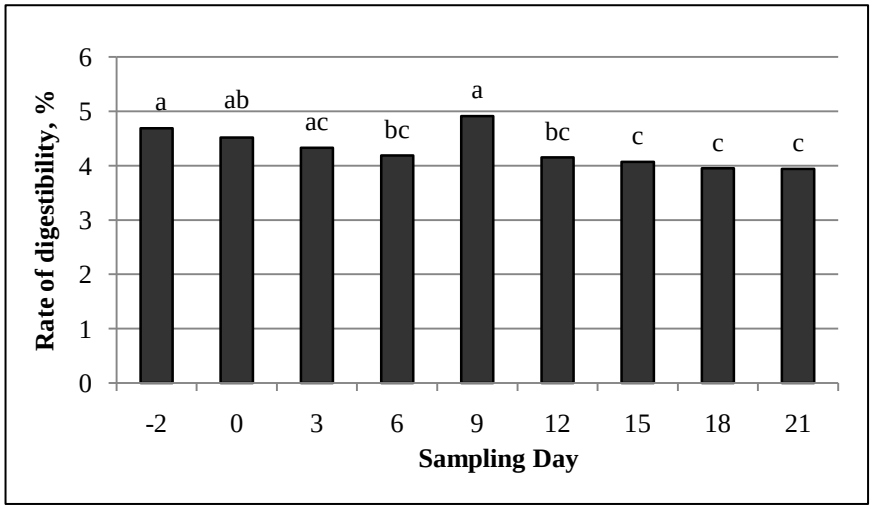


Figure 4.3. Influence of sampling day on rate of digestion, relative to switching from a concentrate-containing diet to a forage-only diet (SE = 0.3 for day 9; SE = 0.2 for all other days).
[abc] Means with different superscripts within row differ ($P < 0.10$).

Rumen pH

A pre-experiment diet × sampling day interaction occurred ($P < 0.01$) for ruminal pH (Figure 4.4). Heifers that received the 70% diet had a lower pH than CONTROL and heifers that received the 35% diet on d -2 and 0. This was expected due to the higher proportion of concentrate in the 70% diet. Similarly, Beck et al. (2005) reported lower ruminal pH before grazing (d -1) in steers limit-fed high concentrate diets than steers fed hay-based diets. By 3 days after the diet switch, 70% had a higher pH than other treatments and remained higher for the remainder of the trial. None of the pH values

observed were physiologically abnormal. An hour(sampling day) interaction also occurred ($P < 0.01$; Figure 4.5) for ruminal pH. Ruminal pH was highest at -1 h with depressions between 2-4 h after feeding and increased again between 8-16 h, with the magnitude of diurnal changes varying by sampling day. Chase and Hibberd (1981) observed similar depressions between 3-9 h after feeding before pH increased to pre-feeding levels.

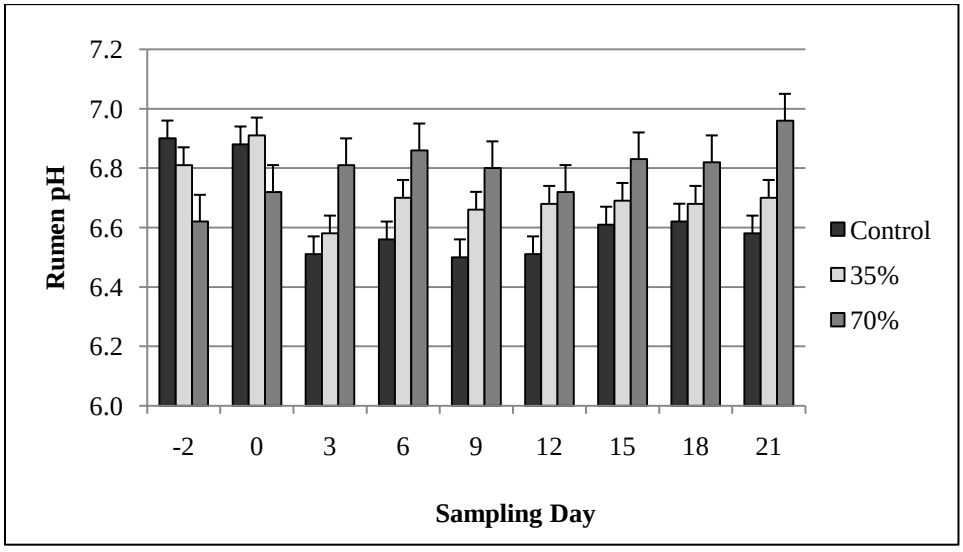


Figure 4.4. Pre-experiment diet × sampling day interaction for ruminal pH ($P < 0.01$; SE = 0.06, 0.06, and 0.09 for CONTROL, 35%, and 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

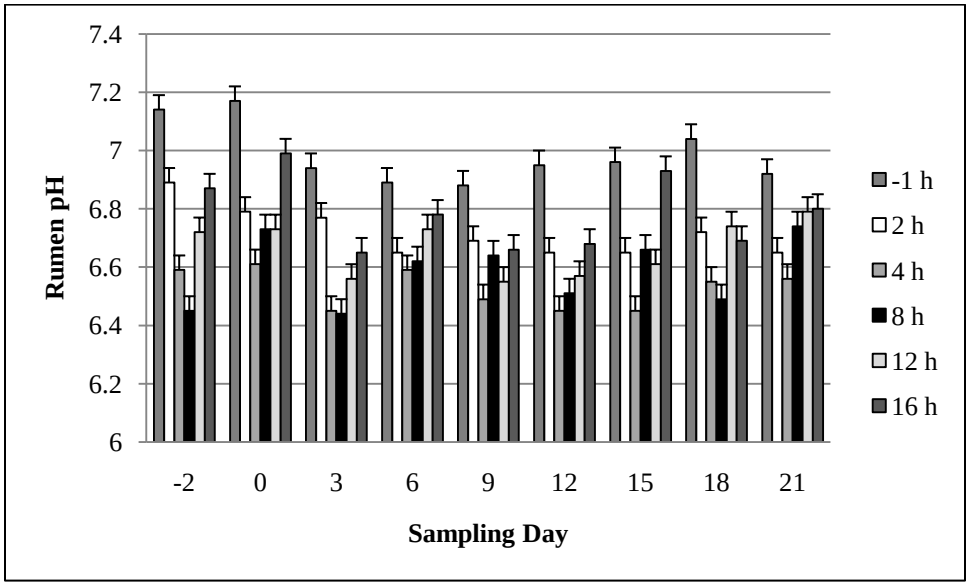


Figure 4.5. Hour(sampling day) interaction for rumen pH, ($P < 0.01$, SE = 0.05). Cows were abruptly switched to an all-forage diet on day 0.

Ruminal ammonia

A diet × hour(sampling day) interaction occurred ($P < 0.01$) for ruminal ammonia (Figure 4.6). Rumen ammonia concentrations declined rapidly for all cows, regardless of diet, probably due to the removal of higher nitrogen-containing diet ingredients (i.e., alfalfa hay, soybean meal, urea). Adams et al. (1987) reported decreased ammonia concentrations in September and October as forage quality decreased with advancing maturity. This is similar to the removal of higher nitrogen-containing ingredients in the current study. When sampled before and immediately after the diet switch, ruminal ammonia concentrations for CONTROL and 35% cows peaked at 2 h after feeding. After the diet switch, ammonia levels rapidly declined. Chase and Hibberd (1987) reported a similar peak 3 h after feeding steers ground corn. Cows from the 70% treatment also exhibited a peak at the 2 h sampling, but ammonia concentrations spiked

again at 12 and 16 h post-feeding before declining after the diet switch. These differences were not observed in later sampling dates. Ruminal ammonia concentrations were below the suggested level of 5 mg/dl described by Satter and Slyter (1974).

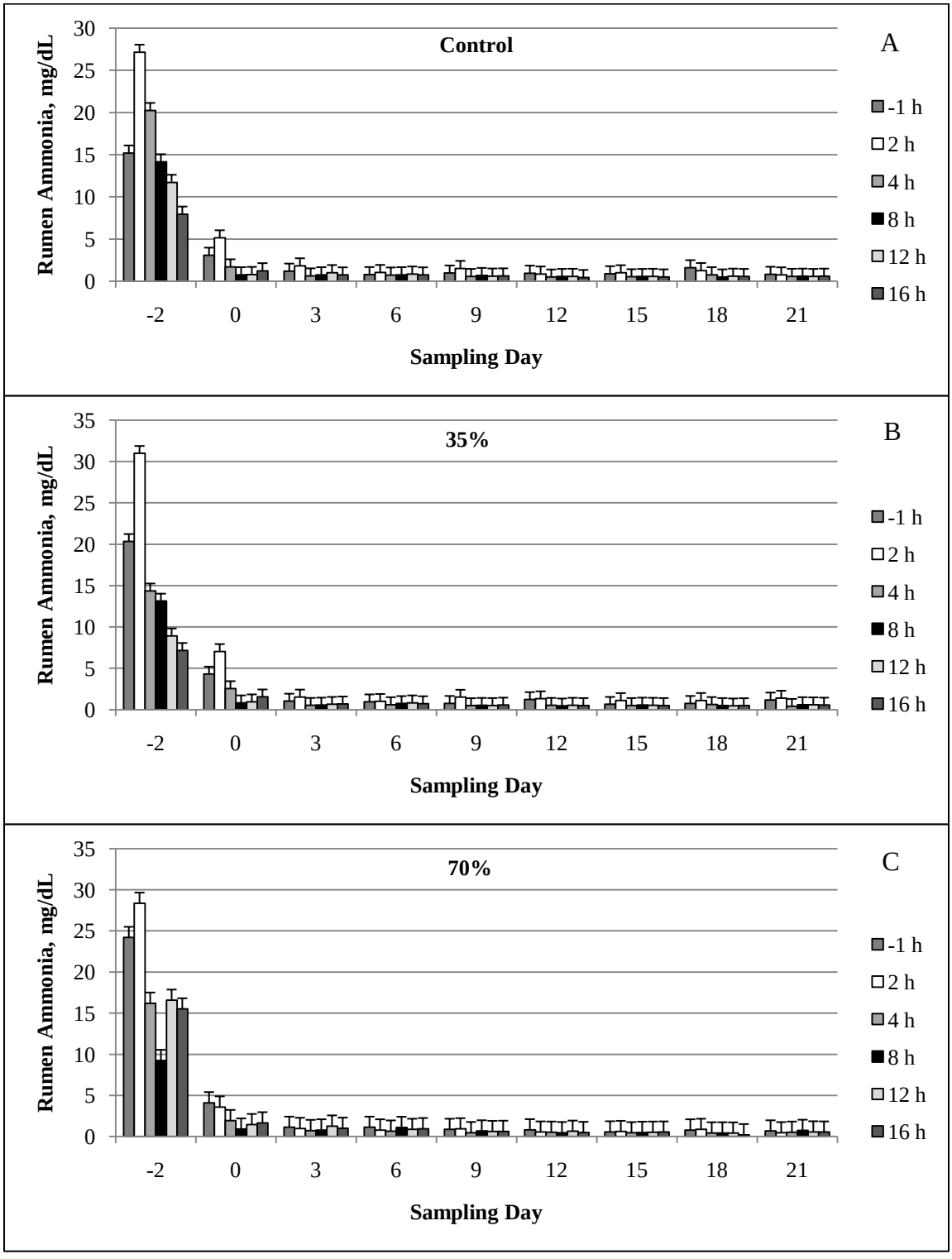


Figure 4.6. A pre-experiment diet × hour(sampling day) interaction occurred ($P < 0.01$; SE = 0.9, 0.9, and 1.3 for A) Control, B) 35%, and C) 70% respectively) for ruminal ammonia. Cows were abruptly switched to an all-forage diet on day 0.

Volatile Fatty Acids

There was a pre-experiment diet × sampling day interaction (P = 0.02) for total VFA production (Figure 4.7). Early in the trial, all 3 treatments had similar levels of VFA production, while after the diet switch the total VFA production for heifers receiving the 70% diet was less than cows receiving either the CONTROL or 35% diets. A pre-experiment diet × sampling day interaction (P = 0.02) occurred for the acetate:propionate (A:P) ratio as well (Figure 4.8). Heifers on the 70% pre-experiment diet had a lower A:P ratio on d 0 and -2. This agrees with Raun et al. (1962) who found that lambs on high concentrate diets have a lower ratio compared with those receiving a 50:50 concentrate to roughage diet. Beck et al. (2005) also reported a lower A:P ratio in steers limit fed high concentrate diets in drylot before being turned out for grazing.

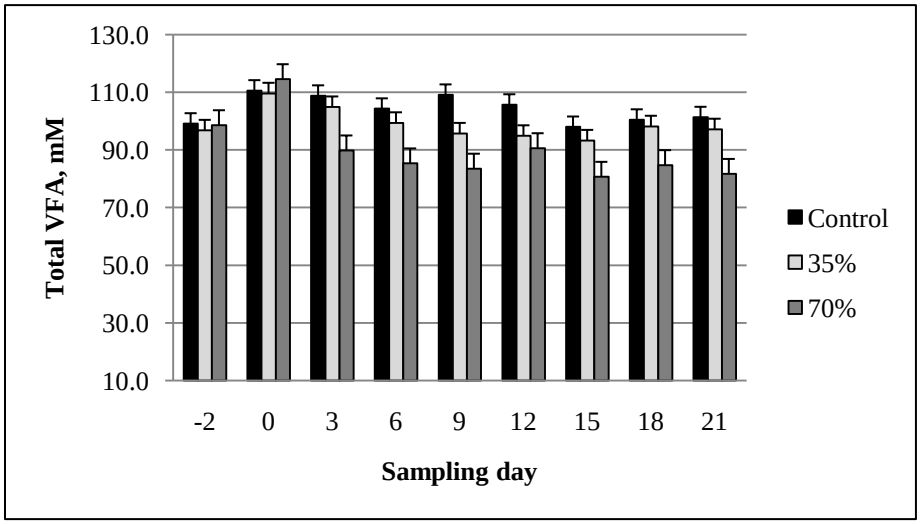


Figure 4.7. A pre-experiment diet × sampling day interaction for total VFA production (P = 0.02; SE = 3.57, 3.64, and 5.14 for Control, 35%, and 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

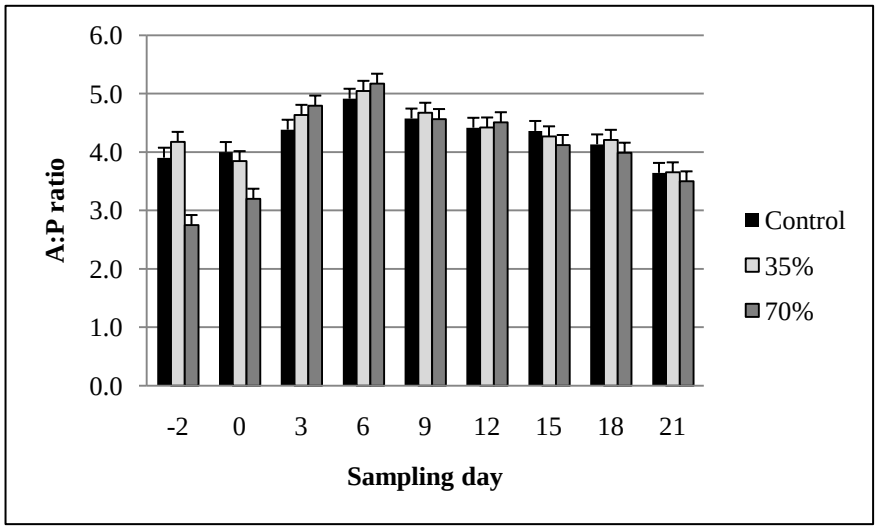


Figure 4.8. A pre-experiment diet × sampling day interaction ($P = 0.02$; SE = 0.17) occurred for the acetate:propionate ratio. Cows were abruptly switched to an all-forage diet on day 0.

Molar proportion of acetate exhibited a pre-experiment diet × sampling day interaction ($P < 0.01$; Figure 4.9). Early in the trial, heifers fed 35% corn or CONTROL diets displayed higher proportion of acetate than heifers fed 70% corn. Similarly, Beck et al. (2005) found that before grazing, acetate concentrations were less in steers limit fed high concentrate diets than steers fed forage-based diets. An hour(sampling day) interaction occurred for molar proportion of acetate as well ($P < 0.01$; Figure 4.10). On d -2, acetate proportions were lowest at -1 h. However, for the remainder of the trial, acetate proportions were highest at -1 h.

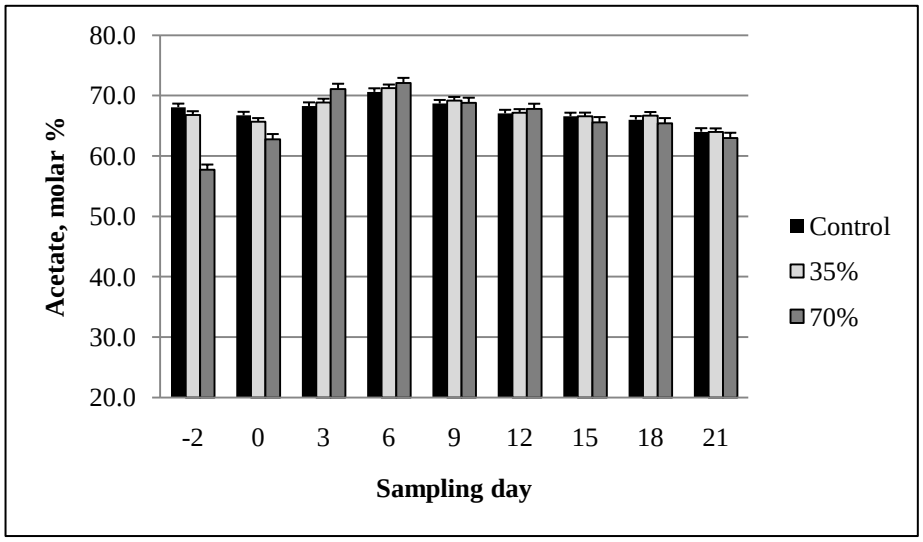


Figure 4.9. Pre-experiment diet × sampling day interaction for molar percentage of acetate ($P < 0.01$; SE = 0.59, 0.60, and 0.85 for Control, 35%, and 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

Molar proportion of propionate also displayed a pre-experiment diet × sampling day interaction ($P < 0.01$; Figure 4.11). Heifers fed the 70% corn diet had higher percentage of propionate on d -2 and 0 compared with heifers fed CONTROL or 35% diets. Similarly, limit-fed steers had higher propionate concentrations than steers fed hay-based diets on d -1 before grazing and on d 3 of grazing (Beck et al, 2005). An hour(sampling day) interaction also occurred for molar proportion of propionate ($P < 0.01$; Figure 4.12). Prior to and following the diet switch, there is more diurnal variation for propionate which may be caused by inconsistencies in the rumen during the switch from concentrate-containing diets to an all-hay diet.

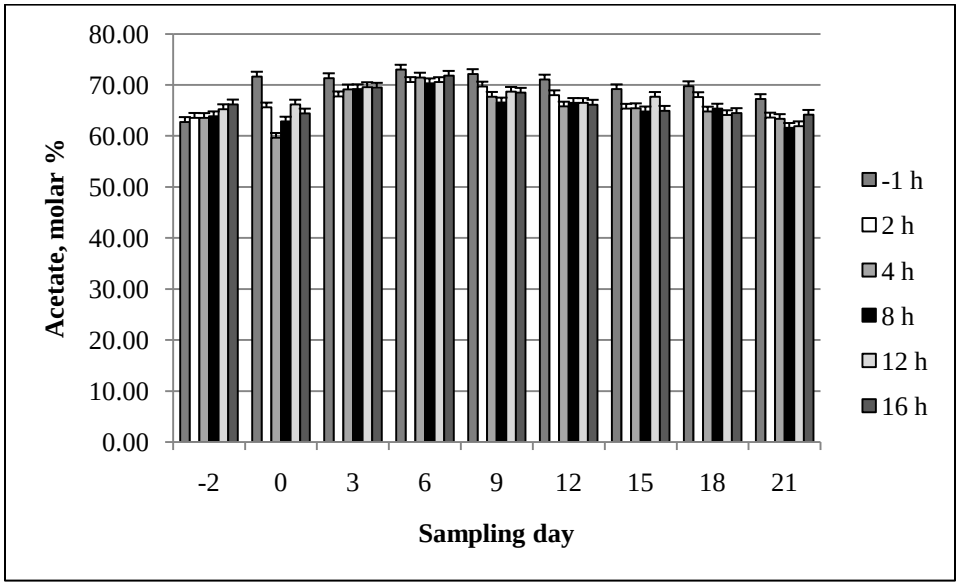


Figure 4.10. Hour(sampling day) interaction for molar percentage of acetate ($P < 0.01$; SE = 0.94). Cows were abruptly switched to an all-forage diet on day 0.

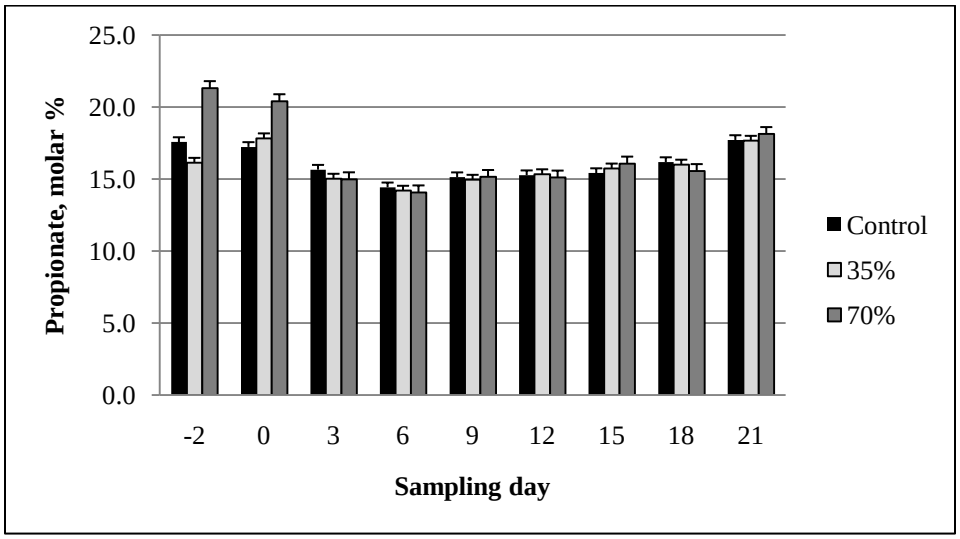


Figure 4.11. Pre-experiment diet × sampling day interaction for molar percentage of propionate ($P < 0.01$; SE = 0.33, 0.34, and 0.48 for Control, 35%, and 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

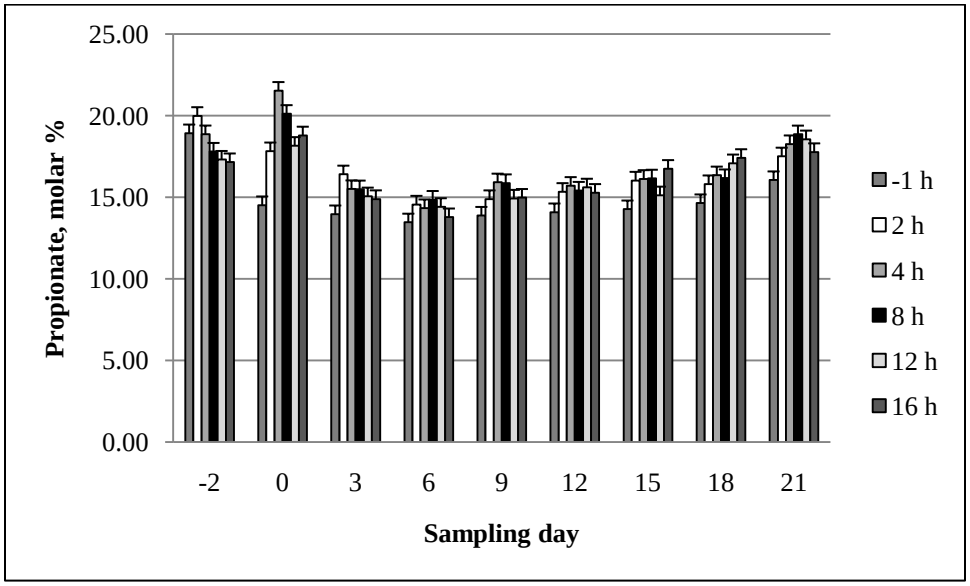


Figure 4.12. Hour(sampling day) interaction for molar percentage of propionate (P < 0.01; SE = 0.53). Cows were abruptly switched to an all-forage diet on day 0.

Molar percent of butyrate exhibited a pre-experiment diet × hour(sampling day) interaction (P = 0.05; Figure 4.13). Before the diet switch, the molar percentage of butyrate increased as level of concentrate in the diet increased. Butyrate levels peaked at 8 h relative to feeding before the diet switch while the Control and 35% were similar throughout the day. More diurnal variation was observed after the diet switch for 35% and Control. After the diet switch, the butyrate molar percentages decreased in the 70% as the experiment progressed, but increased for Control and 35%. Pre-experiment diet had an effect on branched chain VFA molar percentages (P = 0.02; Figure 4.14). Both 35 and 70% had higher levels of branched chain VFA than Control. In addition, there was an hour(sampling day) interaction for branched chain VFA molar percentages (P < 0.01; Figure 4.15). There was a decreasing trend for all sampling hours until d 6. After this

day butyrate levels increased until d 15 before declining for the remainder of the study, with the magnitude of differences varying by sampling day.

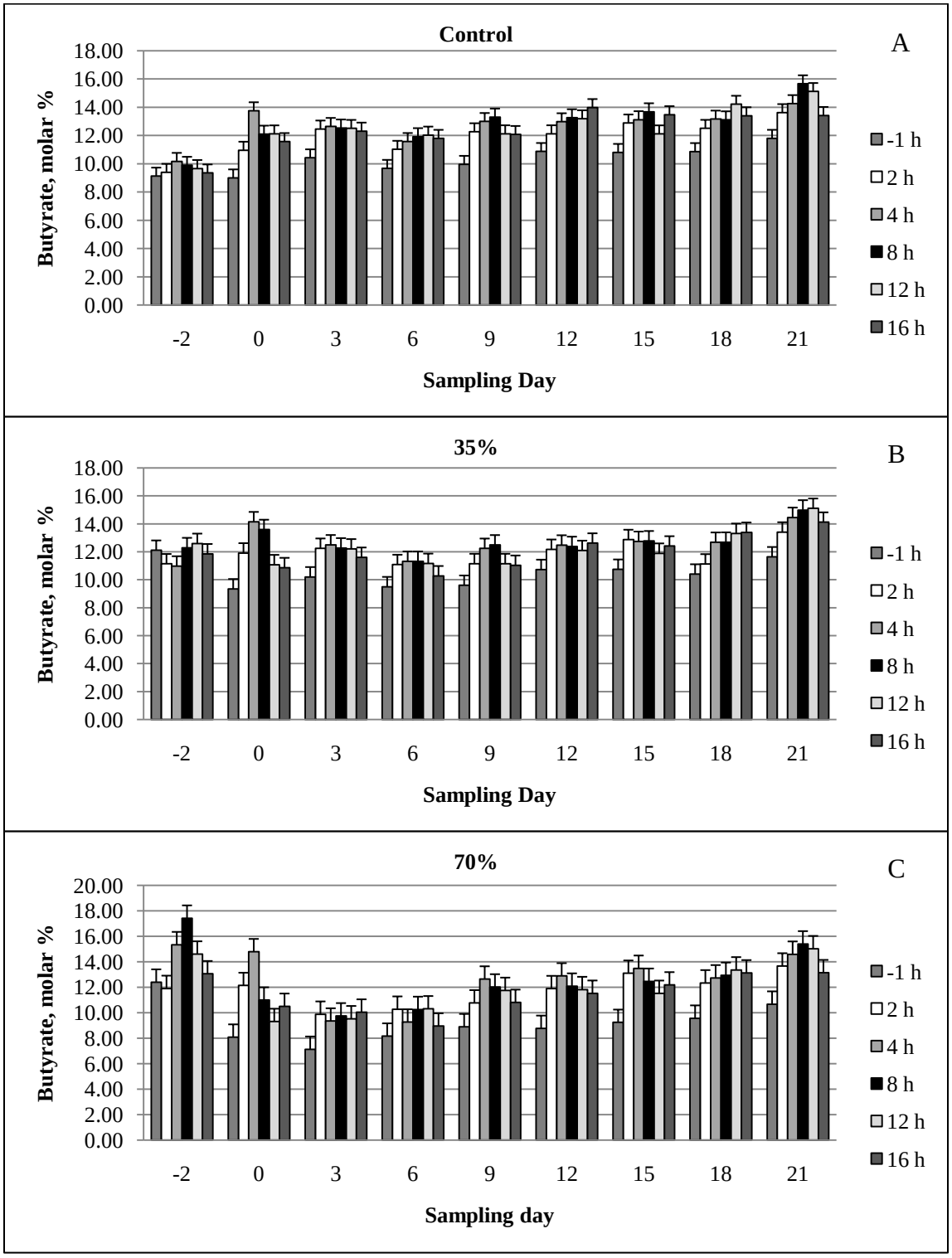


Figure 4.13. A pre-experiment diet × hour(sampling day) interaction occurred for molar percentage of butyrate (P = 0.05; SE = 0.60, 0.71, and 1.0 for A) Control, B) 35%, and C) 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

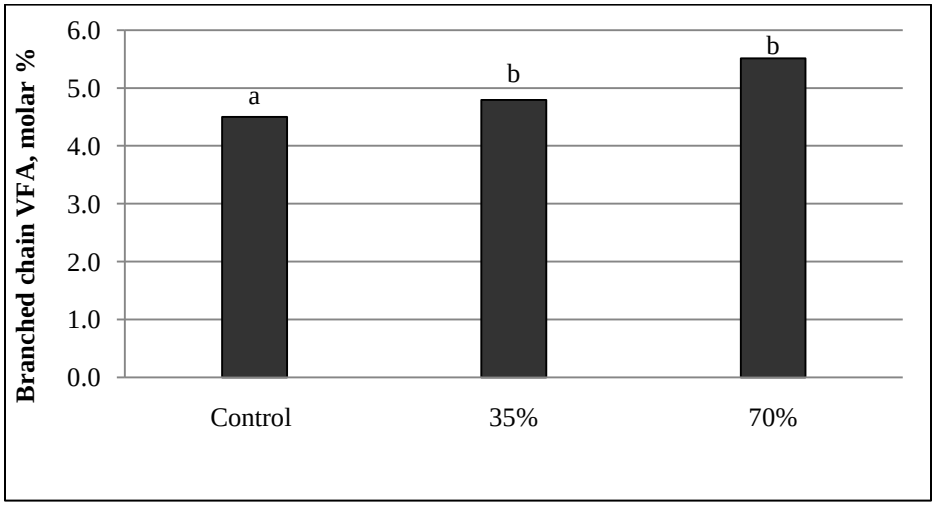


Figure 4.14. Pre-experiment diet effect on branched chain VFA (P = 0.02). Cows were abruptly switched to an all-forage diet on day 0.

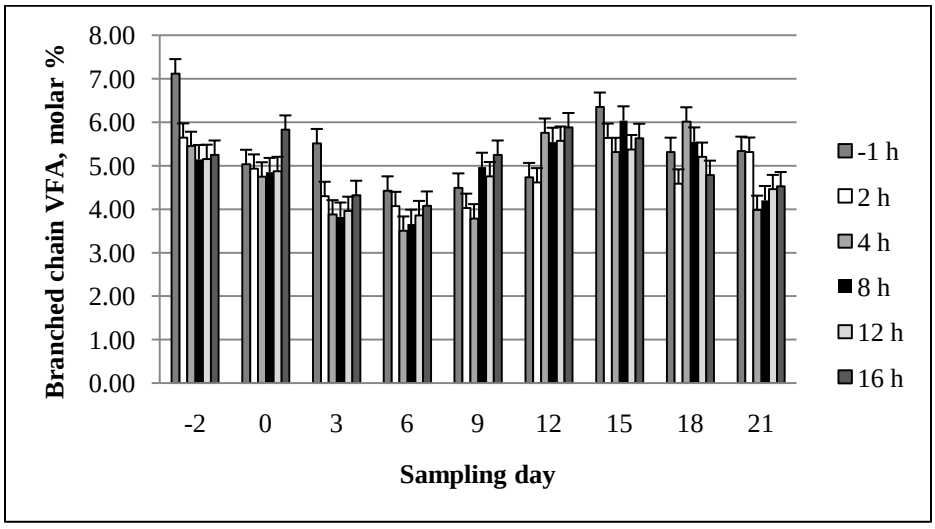


Figure 4.15. Hour(sampling day) interaction for molar percentage of branched chain VFA (P < 0.01, SE = 0.33). Cows were abruptly switched to an all-forage diet on day 0.

Serum Metabolites

A diet × sampling day interaction occurred (P = 0.05) for serum glucose (Figure 4.16). Within each sampling day, glucose concentrations were similar for all cows regardless of pre-experiment diet. However, the response for each diet varied by

sampling day. There was an hour(sampling day) interaction for serum glucose ($P < 0.01$; Figure 4.17). Generally, glucose was highest at -1 h before feeding, dipped to its lowest point 4 h after feeding and returned to near pre-feeding levels by 8 h. The magnitude of differences varied by sampling day. Serum glucose levels for all heifers regardless of treatment were within the normal range (45-75 mg/dL) for cattle suggested by Kaneko et al. (1997).

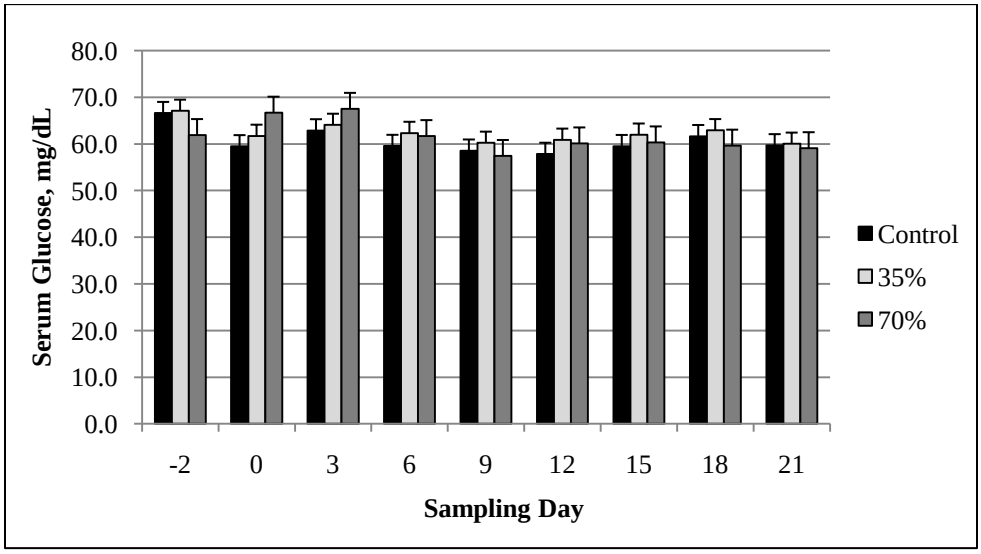


Figure 4.16. A pre-experiment diet × sampling day interaction occurred ($P = 0.05$; SE = 2.4, 2.4, and 3.4 for CONTROL, 35%, and 70% respectively) for serum glucose. Cows were abruptly switched to an all-forage diet on day 0.

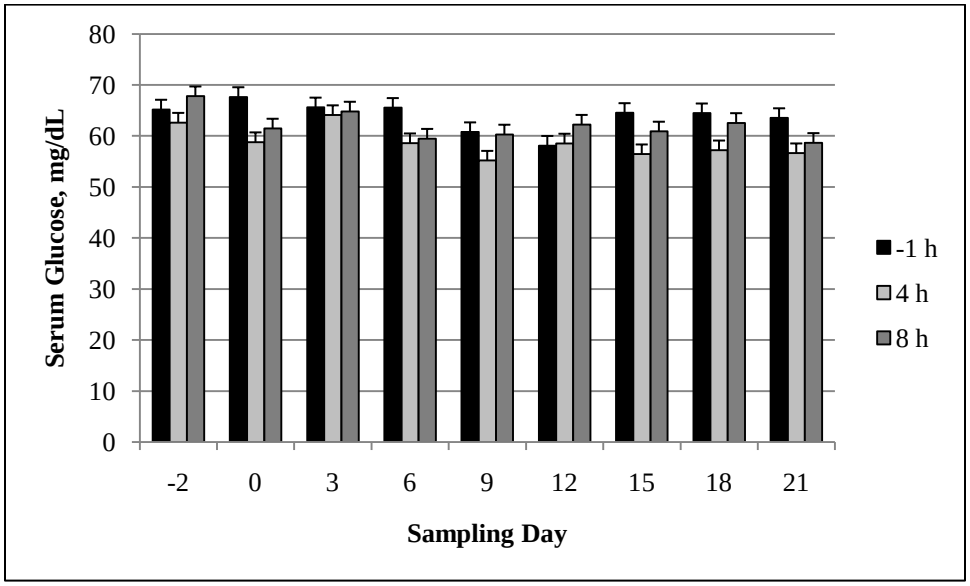


Figure 4.17. Hour(sampling day) interaction for serum glucose ($P < 0.01$, SE = 1.9). Cows were abruptly switched to an all-forage diet on day 0.

Diet × hour(sampling day) interactions occurred ($P = 0.01$) for SUN (Figure 4.18) and serum NEFA (Figure 4.19). After the diet switch, SUN levels, regardless of treatment, were well below the normal range for cattle suggested by Kaneko et al. (1997). Like rumen ammonia concentrations, SUN concentration declined rapidly for all cows. These findings agree with Park et al. (1994) who reported lower SUN concentrations in steers grazing wheatgrass during September and November when forage N was lower compared to May and June. On sampling days immediately before and after the diet switch, CONTROL and 35% cows had lowest SUN concentrations at -1 h relative to feeding and peak SUN concentrations at 4 h post-feeding, with 8 h concentrations intermediate. On the other hand, 70% cows had peak SUN concentrations at 4 h, lowest at 8 h, and intermediate at -1 h. These differences were not observed in later sampling dates.

Serum NEFA concentrations exhibited little diurnal variation for CONTROL and 35% cows, but 70% cows had much higher serum NEFA concentrations at -1 h than 4 or 8 h. These relationships persisted throughout the experiment. Since NEFA concentrations did not increase throughout the trial there is no indication that these heifers were mobilizing fat stores in order to maintain body condition. Park et al. (1994) however, observed higher NEFA levels in steers later in the grazing season.

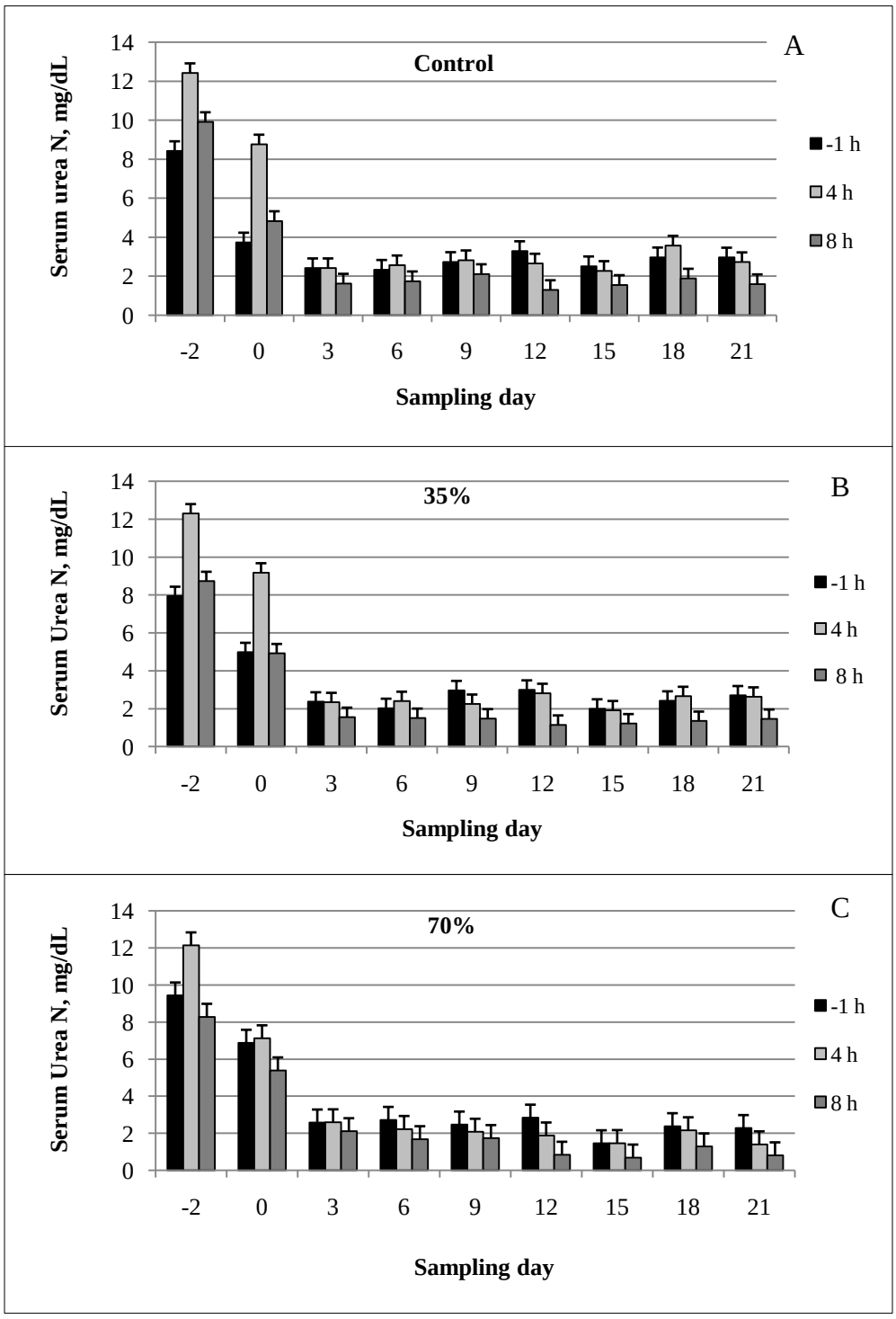


Figure 4.18. A pre-experiment diet × hour(sampling day) interaction occurred ($P = 0.01$; SE = 0.5, 0.5, and 0.7 for A) Control, B) 35%, and C) 70% respectively) for serum urea N. Cows were abruptly switched to an all-forage diet on day 0.

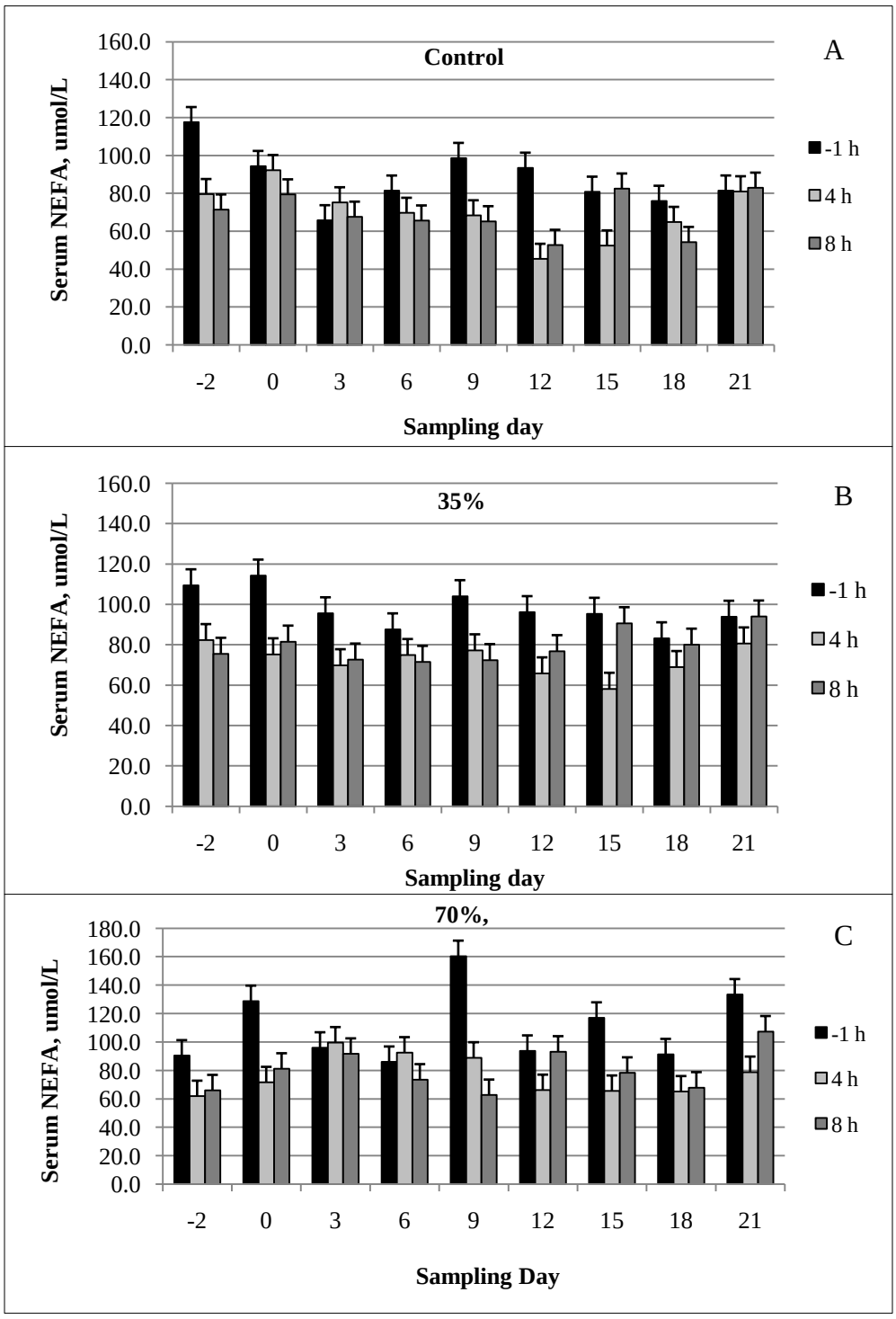


Figure 4.19. A pre-experiment diet × hour(sampling day) interaction occurred (P = 0.01; SE = 8.0, 8.0, and 11.0 for A) Control, B) 35%, and C) 70% respectively) for serum NEFA concentration. Cows were abruptly switched to an all-forage diet on day 0.

Sampling day influenced serum insulin concentrations ($P = 0.02$; Figure 4.20). There was a general decrease in serum insulin concentrations at the beginning of the trial ending on d 6. Serum insulin levels showed an increase on d 9 and 12, followed by a decrease on d 15, and then another peak on d 18 and 21. There was an hour(sampling day) for serum insulin ($P < 0.01$; Figure 4.21). Serum insulin was lowest at -1 h throughout the sampling days. Insulin levels were highest at 4 h after feeding until d 9, when insulin levels became highest 8 h after feeding. Park et al. (1994) reported lower insulin levels in September (0.5 ng/mL) and November (0.37 ng/mL) compared to June (0.63 ng/mL) in steers grazing wheatgrass during advancing stages of maturity. Insulin concentrations discussed in this study were comparable to levels reported by León et al. (2004) for similar heifer types.

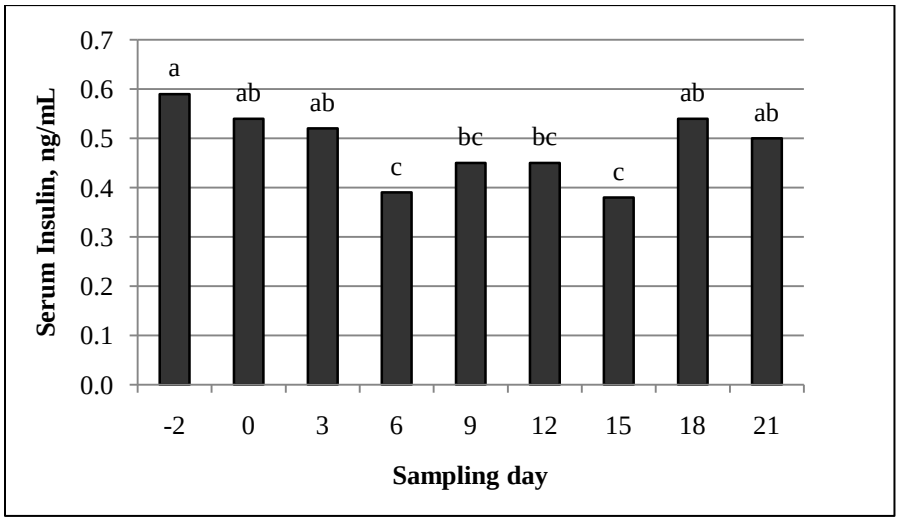


Figure 4.20. Influence of sampling day on serum insulin, relative to switching from a concentrate-containing diet to a forage-only diet (SE = 0.07).
[abc] Means with different superscripts within row differ ($P = 0.02$).

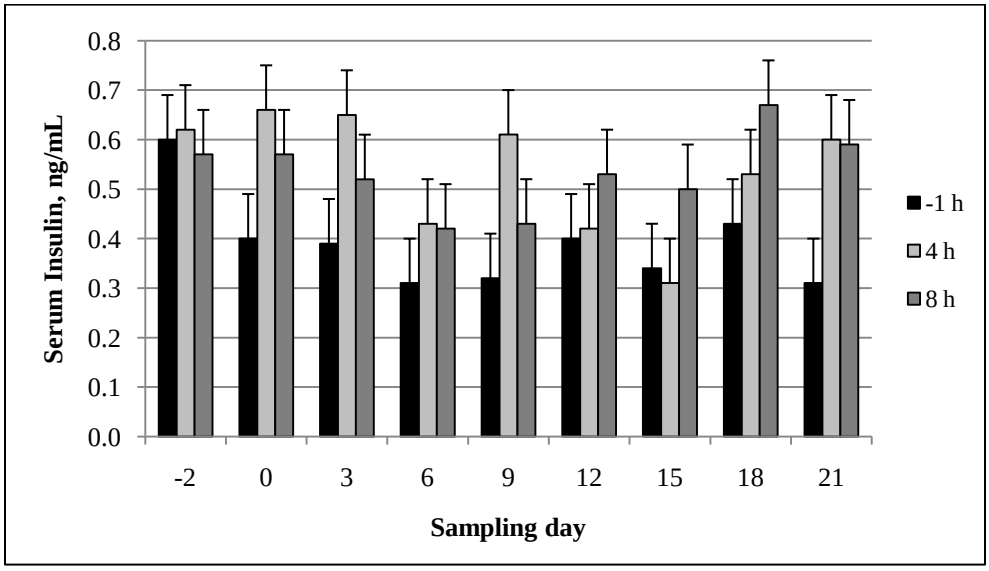


Figure 4.21. Hour(sampling day) interaction for serum insulin ($P < 0.01$); SE = 0.09).

Conclusion

Forage digestibility was depressed when heifers were fed a high-concentrate diet; however, this effect disappeared within 96 h of feeding an all-forage diet. With the removal of protein supplement in the all-forage diets, ruminal NH_3 and SUN concentrations declined rapidly after the abrupt diet switch. In addition, the A:P ratio is narrowed for all treatments after the diet switch from concentrate-containing diets to one of all-forage.

Future research where in situ sampling hours are timed more immediately after the diet switch could target the precise timing of rumen adaptation. Another area of research might include studying animal behavior after being turned out into breeding pastures from confinement. Results from the present study suggest that the rumen can adapt quickly when diets are switched from concentrate-containing to all-forage.

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