ENVIRONMENTAL IMPACT OF WITHHOLDING FEED ON COMPOSITION OF RUMINAL CONTENTS, CARCASS QUALITY, AND CATTLE PERFORMANCE

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CHAPTER I

INTRODUCTION

Currently, feed is withheld from most feedlot cattle being marketed in North America from a minimum of 1 hour to a maximum of about 36 hours prior to harvest. This represents the total time between the consumption of the final meal until cattle are slaughtered. Thereby, it includes the time needed to load the cattle onto trucks at the feedlot, transport the cattle from the feedlot to the packing plant, and for unloading and lairage at the packing plant prior to harvest. Additional time usually is required if finished cattle are marketed through a central stockyards because of the additional time needed to exhibit and sell the cattle and to load and transport them a second time. During lairage at a packing plant, water normally is provided but seldom is feed made available. To have cattle available when packing plants begin operation, typically at 0600, packing plants usually transport some cattle the evening prior to harvest. Often called "starter" cattle, such animals usually have longer periods of feed withdrawal than cattle harvested immediately on arrival at the packing plant. With swine, allowing some time for rest and recovery during lairage at the abattoir has become a standard procedure because this rest period has been associated with an improvement in meat quality (less pale, soft, exudative pork). The incidence of undesirable pork quality (pale, soft, and exudative or dark, firm, and dry) relies upon an optimal rate of pH decline to an ultimate pH. Elevated stress (corticosterone) concentrations have been associated with undesirable pork quality. With ruminants, an increased incidence of "dark cutting" beef has been associated with longer transport and lairage times; greater stress involved with mixing groups of cattle, especially bulls, as often employed in Europe, may be responsible for the high incidence of "dark cutting" beef report from Europe (often over 30%) than from the U.S. (usually under 2%).

Periods of feed withdrawal of 6 to 24 hours often are used by US feedlot operators for several reasons. First, cleaning residual feed from feedbunks is a tedious and time-consuming task; often the feed that is removed is discarded rather than re-fed. To reduce residues that require labor and result in waste, the amount of feed supplied to cattle destined for market often is reduced shortly before cattle are removed from their pens for marketing so all the available feed will be consumed. However, if the value of marketed cattle depends on live weight, often live weight minus a "pencil shrink" of 4 to 6%, feed will not be withheld. This is because feed or water withdrawal will reduce live weight. Indeed, Zinn (1990) has shown that time of day can readily influence live weight, probably as a result of distinct time patterns of feed and water intake.

Some feedlots purposely withhold feed for a longer time period. Withholding for longer times will reduce the amount of feed consumed and thereby can reduce production cost by up to $1.70 for each marketed animal (10 kg feed at $170 per metric ton of feed). The practice of feed withdrawal is more prevalent among feedlots that sell cattle on the basis of carcass weight or carcass value than those feedlots that sell cattle on a live weight basis. This is because producers practicing feed withdrawal presume that even though live weight may be reduced, carcass weight and quality will not be reduced by feed withdrawal. Producers also may withhold feed in an attempt to increase dressing percentage (carcass weight divided by live weight), a factor often included in "formula pricing" purchase agreements between feedlots and packing plants. Finally, packing plants do not provide feed to cattle in lairage to reduce cost and labor. In addition, packing plants may benefit from a feed withdrawal period because it presumably will reduce the quantity of digesta in the tract. This reduces the quantity of waste to be handled and disposed and can reduce the potential for spillage of digesta during evisceration and inspection of the viscera. Despite these multiple reasons for feed withdrawal, the impact of feed withdrawal time on weight and composition of digesta have not been determined. Effects of feed type and additives on the amount and composition of digesta are poorly defined, and ultimate results on carcass weight and value have not been examined in a systematic, scientific fashion. The goals of my research were to examine the potential benefits and detriments of withholding feed prior to harvest of market cattle.

CHAPTER II

REVIEW OF LITERATURE

Numerous physiological factors will be altered by with feed withdrawal. First, when comparing ruminants with nonruminants, ruminants have a large digestive tract capacity, a slow rate of passage of digesta, and much more continuous absorption of nutrients from the digestive tract. Hence, with ruminants, the physiological effects of "fasting" will be delayed, but weight loss will be attenuated. In ruminants, most of the digestive tract contents are found in the reticulo-rumen; contents of the reticulo-rumen average about 16 ± 3 % of body weight (Owens and Goetsch, 1993). In my first experiment, losses in both live weight as well as nutrients from the rumen after various time intervals of feed withdrawal were quantified. Ruminal changes were determined through evacuating ruminal contents and determining the residual amounts after various time intervals. The impact of one feed additive, monensin, and of grain processing on changes in weight and composition of digesta were examined in different studies within that experiment. In my second and third studies, effects of feed withdrawal on weight losses during transit and on carcass measurements were determined using large groups (pens) of feedlot cattle from a commercial feedlot. This literature review provides background information on effects of diet and monensin on ruminal volume and outflow and effects of feed withdrawal on carcass weight and on meat quality.

Rumen Volume

Ruminal contents of 500 kg cattle have been reported to vary from 40 to 125 kg. Dry matter of ruminal contents can be as high as 17%. Liquid in the rumen is partly imbibed within particulate material or solids (Owens and Goetsch, 1986). The rumen is a dynamic organ in which digestion and fermentation processes occur in a liquid environment. According to Bailey (1961), saliva supplied some 70 to 90% of the liquid entering the rumen with the remaining 13 to 24% being supplied by drinking water (Poutiainen, 1968). In cattle, the total liquid volume of ruminal contents can range from 15 to 21% of body weight (Macfarlene, 1976; Owens and Goetsch, 1968) although ruminal volume varies with animal age and diet type.

One can indirectly quantify ruminal volume through administering water-soluble markers and measuring the degree to which the administered marker is diluted. To measure ruminal volume more directly, one can slaughter animals, remove ruminal contents, and weigh components as outlined by Makela (1956). Even though this method permits complete sampling (Van Soest 1985), direct measurement requires a large number of animals and has the disadvantage that volume can be only measured once for each animal. Another method to estimate ruminal volume is to totally remove contents from the rumen of cannulated animals (Reid, 1965). This method can be repeated numerous times with different types of diets and feeding conditions although again, feed or water deprivation can alter feed intake and ruminal contents. Monozygotic twin steers decreased their feed intake by 47% after deprivation of water for one to days (Bond et al., 1976). Cole and Hutcheson (1981) indicated that ruminal fermentation patterns were altered when feed and water was deprived from cannulated steers; three to five days were required for VFA concentrations to return to pre-fast values. Towne et al. (1986) sampled ruminoreticular contents; they completely removed contents, mixed them for five minutes, and returned contents to the rumen. Subsequently, samples were taken 1 h and 4 h later. Results indicated that emptying the rumen of its contents in cattle for five minutes and returning contents to the rumen did not significantly alter the microbial populations, VFA concentration, or liquid passage rate (Towne et al., 1986). However, following evacuation of ruminal contents, cattle consistently consumed more water during the next 24 h period in unpublished work at Oklahoma State. Consequently, water and thereby feed intake patterns over a longer term may be upset following ruminal evacuation.

Effects of Feed Withdrawal prior to Harvest

Although the amount of material present in the rumen can be reduced by withholding feed from cattle prior to harvest, feed withdrawal may have adverse effects on carcass weight or quality. Surprisingly little information is available on the impact of feed withdrawal on carcass characteristics. One study of feed withdrawal was conducted 30 years ago by researchers at Kansas State University (Carr et al., 1969). They detected no reduction in carcass quality with feed withdrawal for up to 48 hours. However, the number of steers in that study was limited for appraising carcass quality effects. They noted that cattle that had been shrunk (subjected to feed withdrawal) were more easily processed than cattle with full intestinal tracts. This led to the suggestion that withdrawing feed from cattle for 1, 2,or 3 days before harvest would economically benefit both feeder and slaughterer (Carr et al., 1968).

Immediately prior to harvest, cattle may experience many potential stressors, e.g., handling and loading onto trucks, transportation to the packing plant, unloading, restriction of food and water, mixing with strange animals and disturbed rest (Connell, 1988). Mitchell et al. (1988) measured physiological responses of cattle during handling, transport, and harvest; they detected arousal of the sympathetic nervous system. A normal practice at packing plants is to hold animals in pens (lairage) prior to slaughter; this provides time for clinical inspection of animal health, it may improve meat quality, and it should decrease gut fill. Gracey (1986) suggested that meat quality could be improved by providing a minimum resting period before harvest of 6 h; even longer times, 12 to 24 h, were preferable for fatigued and excited animals. Meat from animals slaughtered while exhausted may appear dark and fiery suggesting that bleeding has been incomplete; the dark coloration may be attributable to other chemical changes that take place in fatigued muscle. Gracey (1986) also reported that rest before slaughter is essential for the production of meat of good keeping quality. The ultimate pH in steer carcasses was lower for animals that had rested and re-fed for four days, than for animals that had been rested and re-fed for only two days.

Effects of Feed Withdrawal on Meat Quality

Surprisingly, color of muscle tissue was more desirable for steers that had been fasted for 1 or 2 days than for those that had feed continuously or those that had been fasted for 3 days (Carr et al., 1968). Chemical analyses of glycogen content of the liver, water-holding capacity of muscle tissue, and pH of tissue muscle showed essentially no difference, except that fasting markedly decreased glycogen content of the liver (Carr et al., 1968). A long period of transport (11 h) combined with feed withdrawal increased loss in live weight and dressing percentage. Also, transport over a long distance has decreased meat tenderness (Fernandez et al., 1996).

Fasting had no detrimental effect either on carcass quality grade or on the various factors used to determine grade (Carr et al., 1968). This is surprising because fasting would be expected to decrease muscle glycogen and increase the incidence of dark cutters that in turn would reduce quality grade.

Withdrawal of feed (but not water) for 11 hours from 20-week-old Friesian-Holstein calves did not significantly affect live weight (Fernandez et al., 1996). With steers, Kauflin et al. (1969) detected no effect of feed withdrawal (water ad lib) for 1 to 4 d on live weight, but with pigs, fasting (water ad lib) for 24 hours will significantly reduce live weight and liver weight (Warris, 1982; Wittmann et al., 1994). Full body weights may not be a reliable index of carcass weight because live weight can fluctuate drastically with feed consumption and, particularly, with intake of water (Zinn et al., 1990). If restriction of water accompanies restriction of feed, or if feed intake decreases during water restriction, body weight should be lost over time if excretions and evaporatory water losses continue. In contrast, if access to water is not restricted, compensatory water intake or weight fluctuations may mask the loss of weight during feed withdrawal.

Feed withdrawal prior to harvest is a routine practice among poultry producers. Withdrawal of feed from broiler chickens for 12 h did not significantly affect the total live weights of the birds. However, feed withdrawal reduced the weight of the intestine in 7 of 10 groups and of the ceca in 5 of 11 groups; feed withdrawal drastically reduced the amount of feces deposited in the shipping crates (Rigby and Pettit, 1981). Summers and Leeson (1979) reported that when feed was withdrawn from eight-week-old broilers for 10 to 12 hours, intestinal passage rate for feed was increased and body weight decreased if the birds had access to water.

Impact of Feed Withdrawal on Meat Quality

In one recent study of carcasses with dark colored meat (dark cutters), data were collected in 1989 and 1990 from one packer that had packing plants located in Amarillo, TX; Boise, ID; Dakota City, NE; and Garden City, KS. Cattle slaughtered in Amarillo, TX and Garden City, KS had a higher incidence of dark cutters (3 vs 1.1%), a lower quality grade (50 vs 64% choice plus prime), and had a higher dressing percent (64 vs 63%) than those harvested in Boise, ID (Kreikemeier et al., 1990). Seasonal effects were detected, with the highest incidence during August, September, and October (1.1 to 1.4%) than in other months (.4 to .7%). However, no significant effect of chill time on the percent of dark cutters was detected. Chill times of 24 or 48 h had no effect on the percentage of carcasses grading choice plus prime, but carcasses that were chilled 72 or 96 hr before grading resulted in 3 to 5 percent more ($P < .01$) in the choice plus prime carcasses (Kreikemeier et al 1990).

Dark cutting beef is costly. When prorated across all beef harvested, dark cutting costs beef producers approximately $5 for every fed steer and heifer. This $5 charge per animal equals a quarter million dollars annually for a 20,000-head feedyard that turns cattle 2.5 times each year. Overall, dark cutters represent a loss of $132 million for the cattle industry each year (Smith et al.., 1995).

Dark cutting beef presumably is caused by a depletion of muscle glycogen prior to slaughter. Glycogen serves as a substrate for production of lactic acid that causes pH of muscle to drop from 7.0 at harvest to 5.6 after about 24 hours in the cooler. The incidence of carcasses that have dark cutting beef will increase as a result of exhaustive activity during the pre-slaughter period; this leads to depletion of muscle glycogen

(McVeigh and Tarrent, 1983; Kenny and Tarrent, 1984). Since dark cutting meat does not bloom (turn a bright cherry-red color when meat exposed to air), it is discounted at the retail level (Price and Schweigert, 1978).

Shear force is a measure of tenderness of meat tissue. As the length of time feed and water were withheld increases, shear force increases. Jones et al. (1989) noted that steers lost live weight rapidly within the first 24 h without feed and water; even this short time period had detrimental effects by increasing carcass shrink and reducing muscle quality (Jones et al., 1989). Jeremiah et al. (1988) reported that taste panel tenderness scores were better for steers harvested directly from their feedlot pens than for animals that were transported and held without feed for 24 h prior to slaughter.

Impact of Monensin on Ruminal Activity

Since being approved in 1975 as a feed additive to improve efficiency of gain by feedlot cattle, monensin use in feedlots has increased drastically until today most feedlot cattle are fed diets containing this feed additive or other compounds (ionophores) with similar activity. Monensin modifies acid and gas production in the rumen (Schelling, 1984). Monensin also has been reported to depress the rate at which liquids pass from the rumen (Dinius et al., 1976; Lemenager et al., 1979) although Van Nevel and Demayer (1979) did not detect this change in their studies. Schelling (1984) suggested that the depressed ruminal motility prolongs the time feed remains in the rumen for fermentation. Thereby, monensin may increase dry matter digestibility (Dinuis et al., 1976; Thornton and Owens, 1981).

Today, more than 80% of cattle fed finishing diets receive diets containing monensin. By increasing the ratio of propionate to acetate being produced in the rumen, methane production is decreased. However, methane production may rebound in finishing steers over time even though the propionate to acetate ratio remains elevated. Presumably this rebound reflects an increased ruminal residence time and thereby an increase in the extent to which organic matter is fermented in the rumen (Johnson et al., 1995). Ruminant wastes also contain monensin that can inhibit methane production from wastes. Such a decrease in methane yield occurred within just a few days after the waste from animals fed monensin was first added to fermenters; by 9 days of daily feeding the fermenters waste from cattle fed monensin, methane production was severely inhibited (Varel and Hahimoto, 1981).

Methane is a greenhouse gas that accounts for 18% of anthropogenic warming, second only to carbon dioxide in its contribution to human-induced climate change (RLEP, 1997). Methane, a product of ruminal fermentation produced by methanogenic bacteria, is eructed and expired by ruminants into the air. Ruminant livestock are responsible for about 22% of anthropogenic methane emissions globally and for 21% in the US (RLEP, 1997). The most promising and cost effective approach to reduce methane emissions from US livestock is to improve productivity so that less methane is emitted per unit of product produced. Monensin depresses methane production, at least temporarily, and enhances energy efficiency. Whether monensin residues in ruminal contents will inhibit methane yield by fermentation flasks is not known. Certainly, monensin concentration, as a percentage of fluid or as a ratio to fermentable organic matter, is much lower in ruminal contents than in fecal material. So whether feeding methane production in fermenters will be depressed as much by ruminal contents as by feces from cattle fed monensin is not yet known.

Cattle lose roughly 6% of their gross energy intake as methane gas. Besides being oxidized to carbon dioxide, methane destroys ozone; thereby, it is considered to increase the climatic greenhouse effect (Tamminga, 1996). Rate of methane production varies with diet digestibility, level of intake, carbohydrate type, forage processing, liquid content, ionophore feeding and source, and microbial flora of the rumen (Johnson and Johnson, 1995).

CHAPTER III

IMPACT OF WITHHOLDING FEED ON WEIGHT AND COMPOSITION OF RUMINAL CONTENTS

Abstract

To determine how weight and composition of ruminal contents change during fasting, ruminally cannulated heifers (410 kg) were used in an experiment consisting of three trials. In the first trial, ruminal contents of 10 heifers were fully evacuated at 0, 12, 24, and 36 hours after the last meal of an 84% concentrate diet based on rolled corn. Mass of wet ruminal contents decreased steadily from 1 to 24 h after feeding but the decrease was slower thereafter. At 24 h, loss of weight of ruminal contents averaged 20% while loss of organic matter averaged 44%. In trial 2, six heifers were fed the same diet as above with either 0 or 33 ppm of monensin added. At 24 h, loss of weight of ruminal contents averaged 19% while loss of ruminal organic matter averaged 68%. In trial 3, six heifers were fed feedlot diets (92% concentrate) based on either high moisture corn or steam flaked corn. Weights of wet and dry ruminal contents were considerably lower with these processed grain diets than with the rolled corn diets used in earlier trials. Twenty-four hours after feeding, wet weight had decreased by 7% but organic matter still averaged 45%. Live weight losses at 24 h for the three trials averaged 2.0, .4 and .7%. With 24 hours of feed withdrawal, ruminal pH had increased to values above 6.5; less acid conditions permit fiber digestion to resume. The decrease in organic matter content of the rumen indicates that the "pollution potential" of ruminal contents for packing plants could be reduced by 44 to 68% by withholding feed for 24 h prior to harvest.

(Key words: Feed withdrawal, COD, Rumen contents.)

Introduction

At the packing plant, each feedlot steer yields about 23 kg of partially digested wet material from the rumen that contains about 5 kg of dry matter (Owens and Goetsch, 1986). Possessing a very pungent, penetrating, and persistent odor, ruminal contents are a major waste stream for packing plants. A plant harvesting 5,000 cattle daily must dispose of 115 metric tons of ruminal contents containing 25 metric tons of dry matter each day. Currently, most ruminal contents are spread on land as a fertilizer although small amounts are processed through waste treatment plants or lagoons. At a few packing plants, liquid is expressed leaving a residual solid that can be incorporated into feedlot diets. Withholding feed from cattle for 24 to 48 hours prior to marketing would be expected to substantially reduce the quantity of ruminal contents that needs to be handled and disposed. Although feed withdrawal prior to marketing is a routine practice in the poultry industry, effects of feed withdrawal on the mass and composition of ruminal contents have never been measured with feedlot cattle. In addition to reduced waste disposal for packing plants, withdrawal of feed for 24 hours would reduce feed use by 7 to 11 kg per animal; this would reduce production cost (at $170/ton of feed) by $1.20 to $1.87 per animal. The objective of this research was to determine the impact of feed withdrawal on weight and composition of ruminal contents.

Material and Methods

Various diets and feed withdrawal times were used in 3 different trials. In Trial 1, an 84% concentrate diet containing rolled corn (Table 1) was fed. Feed withdrawal times were 0, 12, 24, and 36 hours using 10 heifers in a 4-period Yoden square for a total of 40 ruminal evacuations. In Trial 2, six heifers were fed the same diet with or without addition of monensin at 33 ppm (dry matter basis) for four periods in a Yoden square design. Feed withdrawal times were 0, 24, and 36 hours. For Trial 3, six heifers were transported to Goodwell, OK and fed feedlot diets (92% concentrate) composed of either high moisture corn or steam flaked corn (Table 2) for two periods in a crossover design. Feed withdrawal times were 0 and 24 hours.

In each trial, ruminally cannulated heifers (340 to 390 kg) were used; ruminal contents were removed using a suction device either immediately after feeding or 12, 24, and 36 h later using a vacuum device. Ruminal contents were sieved twice (0.63 x 0.63 and 0.31 x 0.31 cm square pore mesh screen) manually to separate the particulate matter from the sieved liquid phase; each of these phases was weighed, mixed thoroughly and sampled (Garza, 1990). After weighing and sampling, the remaining ruminal contents were manually returned to the rumen. Evacuating, sieving, sampling, and replacing ruminal contents took about 20 min per animal.

Immediately at sampling, a 1 L sub-sample of the liquid phase was placed in a graduated cylinder and weighed to determine density; pH of the ruminal liquid was measured. Thereafter, particulate and liquid sub-samples were frozen until chemically analyzed. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were calculated according to APHA, AWWA, and WPCF (1985). Animals were fed their diets for a minimum of 7 days prior to each evacuation to avoid carryover effects; cattle were rotated among withdrawal times on different weeks so animal-to-animal differences could be removed statistically. In each experiment, cattle were fed one hour before the initial ruminal evacuation began. The quantity of feed provided was near the quantity that would be consumed by cattle given ad libitum access to feed, but feed remaining after 2 hours was removed to avoid "nibbling" of feed throughout the day. Cattle had continuous access to water. Cattle in a feedlot usually eat several small meals throughout the day (Stricklin, 1986; Hicks, 1989), often consuming much of their feed when initially provided in the morning and evening (Young, 1986). Hence, relative to feedlot cattle, our 24-hour feed withdrawal time may equate more closely with skipping one feeding rather than two feedings for cattle fed twice daily.

Ruminal sieved liquids and particulate sub-samples were analyzed for dry matter, organic matter (dry matter minus ash), starch (Streeter et al., 1989), acid detergent fiber (Goering and Van Soest, 1970), and chemical oxygen demand (APHA, 1985). To determine the total amounts of each within the rumen, analyzed concentrations were multiplied by weights of each separated fraction and summed.

Total volume of liquid in the sieved liquids from each evacuation was calculated as weight of sieved liquids divided by density of sieved liquids multiplied by moisture content of sieved liquids. Volume of water in particulate matter was considered to equal the weight of moisture lost during drying the sub-sample. Total ruminal water, estimated in liters, was the sum of liquid in the sieved liquids added to liquid in particulate matter. In contrast to those volume measurements, total weight of wet or dry ruminal contents was the sum of the measured masses in the two fractions. In the first two trials, jugular or coccygeal samples of blood were obtained and centrifuged to separate plasma for measurement of plasma glucose concentration by the procedure of using o-toluidine method (Dubowski, 1962) at various times of feed withdrawal. In addition, ruminal acetate and propionate were measured by GC using a packed column and a flame ionization detector.

Effects of time of feed withdrawal on quantities of each component in the rumen were compared using GLM procedures of SAS (SAS, 1988). Classes included animal, period (week of study), and feed withdrawal time. In trials with multiple ruminal evacuation times, linear and quadratic effects of time were determined using orthogonal contrasts. In addition, dilution or decay rates (k) for changes over time were calculated as the natural logarithm of final (N) divided by the initial (N_0) values as divided by the time (t) interval between sampling times as $[(\ln (N/N_0)) / t]$ based on the decay equation ($N = N_0 e^{-kt}$). Decay rates were compared for different times within each trial; for comparison among trials, decay values at 24 h were compared. To examine impact of animal on ruminal measurements or decay rates, animal effects were examined.

Results and Discussion

In trial 1, weight of organic matter in the rumen decreased at fractional rates of 1.8, 4.4 and 2.4%/h for the first, second, and third 12 hour period of feed withdrawal, respectively. Rate of organic matter decrease tended to be fastest from 12 to 24 h than at other time periods. By 24 hours after feeding, ruminal solids (dry matter, organic matter, fiber, screened solids) all had decreased to about half the values measured immediately after feeding (Table 3). A disappearance rate of 2.89%/h would result in loss of 50% in 24 h. In contrast, total weight of ruminal contents and liquid remained relatively stable or increased over time, with total weight of ruminal contents first increasing, then decreasing, and again increasing during the first, second, and third 12 hour time periods (+1.2; -.08; +1.3%/h), respectively, as shown in Table 4. Ruminal pH also increased during fasting.

Comparisons of ruminal contents after feeding versus 24 hours later for steers fed diets with or without monensin are presented in Table 5 and rates of change are presented in Table 6. In this trial, weights of ruminal contents, screened solids, dry matter, organic matter, fiber, and starch each decreased ($P < .05$) during the withdrawal period similar to observations in Experiment 1. Ruminal concentrations of acetate and propionate decreased by 51.8% and 32.8%, respectively, when averaged across monensin levels. Neither ruminal concentrations nor ratios of VFA were altered by feeding of monensin unlike most studies from the literature. However, the decrease in ruminal concentration over time was less for propionate than for acetate indicating that the ratio of acetate to propionate was increasing during feed withdrawal. Based on these VFA changes, one would not expect that methane production from fermenters acting on ruminal contents would be decreased by addition of monensin to the diet of steers being harvested.

However, liters of liquid in the rumen tended to increase with time and ruminal pH increased ($P < .05$) markedly, presumably because residual material remaining to ferment had decreased while input of salivary buffers had continued. Considering potential adverse effects of longer withdrawal times on animal welfare and on carcass measurements, we concluded that 24 hours was the most feasible and practical feed withdrawal time. No effects of monensin on ruminal measurements were detected; however, a trend was detected for blood glucose to increase during fasting with the control diet but to decrease with the diet containing monensin.

Comparisons of ruminal measurements after feeding versus 24 hours later for heifers fed high moisture or steam flaked corn are presented in Table 7 and rates of change are presented in Table 8. Time effects again were detected for most measurements similar to those noted in previous trials. However, in this trial, volume of dry material in the rumen was considerably lower than in earlier trials. This may be due to faster digestion of feed organic matter in the rumen leaving less ruminal residue from previous meals for cattle fed high moisture and steam flaked corn than for cattle fed dry rolled corn in the previous trials. Quantity of liquid in the rumen increased over time. Effects of diet on most measurements also were detected; some interactions between diet and time also were significant. These indicate that rate of ruminal digestion and passage differed with grain form.

Significant differences between individual heifers were detected for most measurements of quantity of individual components in the rumen in both Trial 1 and Trial 2. The only direct measurements that were not impacted ($P < .05$) by animal were plasma glucose and ADF and COD as a percentage of dry matter (in both trials) and ash as a percentage of dry matter in Trial 2. In Trial 3, the only animal differences detected were in live weight and starch as a percentage of ruminal dry matter. These suggest that differences among animals may be substantial in quantities of material recovered from the rumen and that experimental designs that can remove animal differences, i.e., crossover or Latin squares, may be a preferable experimental design. These results support the conclusion of Teeter (1981) that ruminal mass and fluidity differ markedly among animals but were reasonably stable across time within an animal.

In contrast, differences between animals for rates of disappearance from the rumen generally were not significant. No animal effects on disappearance rates were detected in Trial 1. However, in Trial 2, significant differences among animals were noted for disappearance of wet weight, of ruminal particulate matter, of imbibed water, and for ash, both in kg and as a percentage of dry matter. In Trial 3, the only significant differences among animals were noted for rates of decline in ruminal starch, both in kg and as a percentage of dry matter. This suggests that despite differences in quantity of material in the rumen, that may vary with level of feed intake, rate of loss due to outflow or digestion either were relatively constant among animals or precision of measuring changes was so low that animal effects could not be detected. In a previous study of lactic acidosis (Owens et al., 1998) substantial differences between animals were detected in potential for lactic acid to accumulate during incubation of ruminal contents, so it seems surprising that rates of fermentation would be similar among animals. It is unfortunate that concentration of some indigestible particle component, e.g., lignin, was not determined so that ruminal disappearance via passage might be separated from disappearance via fermentation to test this concept more directly.

A summary of measurements over time across these three trials is presented in Table 9. Live weight loss during the 24 h averaged just under 3% or about 11.3 kg. Total mass (liquid plus solids) in the rumen declined a mean of 18% or by about 6.3 kg. The difference, 5 kg, would include loss of digesta from other segments of the digestive tract and evaporative water loss as well as loss of tissue fluids and solids. On a percentage basis, loss of dry matter (55%) and organic matter (58%) from the rumen were much greater than for fluid. These decreases in dry matter and organic matter represent the sum of digestion and passage; changes in ash content would include input from saliva and outflow to the abomasum. Disappearance of starch (84%) was considerably greater than disappearance of ADF (44%) or COD (50%). The fact that COD did not disappear as rapidly as organic matter suggests that lipid concentration of digesta was increasing.

Unfortunately, ether extract concentrations were not measured in these trials. Disappearance of organic matter, fiber, and chemical oxygen demand averaged between 2% and 3% per hour. Note that during the feed withdrawal period, ruminal pH increased into a range that fiber digestion could resume provided cellulolytic organisms were still present and active.

Rate of disappearance was lower for fiber (ADF) than for dry matter or organic matter, indicating that fiber was being concentrated slightly during feed withdrawal due to continued digestion of non-fibrous feed components such as starch. Chemical oxygen demand, closely reflecting organic matter, indicates that the "pollution potential" should be reduced by 40 to 60% by withholding feed from cattle for 24 hours. In these studies, live weight was reduced an average of 3% or 11 kg by withholding feed for 24 hours although the decrease in live weight during feed withdrawal was much less with the processed grain diets. Ignoring potential effects of 24 hours of feed withdrawal on hot and cold carcass weights and on carcass quality, withholding feed prior to harvest may be beneficial economically by substantially reducing the amount of dry matter in ruminal digesta that cattle packing plants must handle. However, feed withdrawal may be costly to producers that sell cattle on a live weight basis or even for those selling cattle on a carcass weight basis if loss in carcass weight parallels the loss in live weight. Only half of the decrease in live weight at 24 h of feed withdrawal could be attributed to loss in weight of ruminal contents.

Implications

Withholding feed from cattle decreased weights of ruminal dry matter, organic matter, and fiber rapidly for the first 24 hours and more slowly thereafter. However, water displaced much of this ruminal dry matter so that total weight of ruminal contents was not decreased consistently by a 24-hour fast. Withholding feed for 24 hours prior to harvest should decrease the quantity of organic matter at packing plants by about 50%. However, carcass weight losses and adverse effects on carcass quality, factors not measured in this study, may make feed withdrawal costly for cattle producers.

Table 1. Composition of diet fed (as fed).

Ingredient	% of diet
Corn, rolled	82.65
Cottonseed hulls	12.00
Supplement	3.53
Supplement composition, %	
Cottonseed meal	37.5
Soybean meal	18.5
Ground corn	46.5
Urea, 287% CP	7.5
Limestone, 38%	20.5
Potassium chloride	46.5
Zinc sulfate	0.075
Salt, trace mineral	5.6
Rumensin, 80 g/lb.	0.35
Tylan, 40 g/lb.	0.235
Vitamin A, 30,000 IU/g	0.205

Table 2. Composition of high moisture corn and steam flaked corn diets, % dry matter.

Ingredient	High Moisture Corn	Steam Flaked Corn
Steam flaked corn	0	78.15
High moisture corn	78.15	0
Corn Silage	4.50	4.50
Alfalfa Hay	5.50	5.50
Molasses	1.50	1.50
Fat	2.00	2.00
Cottonseed meal	2.85	2.85
Supplement	5.50	5.50
Composition of diet		
Protein, % of DM	12.80	12.8
Ca, % of DM	.60	.60
P, % of DM	.34	.34
K, % of DM	.70	.70
Monensin, g/ton	33	33
Tylosin, g/ton	111	111
NEm, Mcal/cwt	96.8	96.9
NEg, Mcal/cwt	64.4	64.6

Table 3. Influence of feed withdrawal time on body weight, ruminal measurements, and blood glucose.

	Fasting time					Probabilities P <		
Measurements	0 h	12 h	24 h	36 h	SEm	Animal	Linear-Time	Quadratic-Time
Animal weight, kg	356.2	352.5	348.9	342.1	1.643	0.01	0.01	0.65
Ruminal contents								
Total weight, kg	35.09	34.55	28.11	28.47	0.868	0.01	0.01	0.09
Total weight, % of BW	9.19	9.78	8.03	8.30	0.236	0.01	0.01	0.01
Particulate matter, kg	17.69	14.89	9.99	8.07	0.636	0.01	0.01	0.09
Particulate, % of wet wt	50.63	43.31	36.00	28.56	2.166	0.01	0.01	0.99
Particulate DM, %	37.44	34.90	34.01	31.94	1.144	0.55	0.01	0.01
Imbibed liquid, % of liquid in rumen	40.74	34.77	28.62	22.61	1.790	0.01	0.01	0.97
Liquid, L	27.73	28.33	23.85	24.83	0.793	0.01	0.01	0.01
Dry matter, kg	7.36	6.23	4.26	3.63	0.274	0.01	0.01	0.09
Dry matter, % of BW	2.06	1.76	1.22	1.06	0.078	0.01	0.01	0.09
Rumen contents, % DM	21.12	18.04	15.32	12.78	0.945	0.01	0.01	0.96
Organic matter, kg	6.89	5.77	3.85	3.25	0.264	0.01	0.01	0.09
Ash, kg	0.50	0.48	0.38	0.36	0.026	0.01	0.01	0.20
Starch, kg	0.71	0.54	0.28	0.18	0.103	0.01	0.01	0.61
ADF, kg	2.53	1.95	1.38	1.10	0.164	0.02	0.01	0.70
COD, kg	6.91	6.27	4.06	3.65	0.320	0.02	0.01	0.03
Organic matter, % of DM	93.40	92.46	89.74	89.06	0.571	0.02	0.01	0.15
Ash, % of DM	7.00	7.83	9.28	10.32	0.530	0.71	0.01	0.67
Starch, % of DM	9.24	8.24	5.51	4.62	1.741	0.02	0.05	0.65
ADF, % of DM	33.52	31.85	33.37	28.85	2.407	0.21	0.28	0.40
COD, % of DM	95.56	101.52	97.12	101.59	3.894	0.08	0.46	0.29
pH	5.67	6.33	6.65	7.23	0.135	0.84	0.01	0.33
Plasma glucose, mg/dl	71.2	76.2	72.2	80.7	3.061	0.01	0.10	0.13

Table 4. Influence of feed withdrawal time on fractional rates of change in body weight, ruminal measurements and blood glucose.

	Fasting time				Probabilities P<		
Fractional rate of change, %/h	0-12 h	12-24 h	24-36 h	SEm	Animal	Linear-Time	Quadratic-Time
Animal weight, kg	-0.13	-0.09	-0.11	0.076	0.99	0.83	0.74
Ruminal contents							
Total weight, kg	-0.12	-1.74	0.15	0.373	0.99	0.63	0.01
Total weight, % of BW	0.01	-1.66	0.26	0.383	0.99	0.67	0.01
Particulate matter, kg	-1.31	-3.79	-2.11	0.597	0.46	0.38	0.02
Particulate, % of wet wt	-1.19	-2.05	-2.27	0.711	0.68	0.33	0.72
Imbibed liquid, % of ruminal liquid	-1.07	-2.19	-2.34	0.737	0.51	0.27	0.61
Liquid, L	0.24	-1.44	0.39	0.495	0.99	0.84	0.02
Dry matter, kg	-1.51	-3.43	-1.33	0.774	0.97	0.88	0.06
Dry matter, % of wet weight	0.01	-1.65	0.26	0.007	0.99	0.94	0.82
Dry matter, % of BW	-1.38	-3.34	-1.23	0.861	0.94	0.89	0.05
Rumen contents, % DM	-1.39	-1.68	-1.49	0.861	0.98	0.94	0.82
Organic matter, kg	-1.60	-3.69	-1.41	0.837	0.97	0.88	0.06
Ash, kg	-0.43	-1.78	-0.64	0.680	0.80	0.84	0.17
Starch, kg	-2.50	-17.12	8.20	6.196	0.99	0.30	0.03
ADF, kg	-1.96	-3.13	-3.03	1.343	0.98	0.60	0.71
COD, kg	-0.92	-3.88	-1.17	0.788	0.83	0.83	0.01
Organic matter, % of DM	-0.09	-0.26	-0.08	0.091	0.99	0.92	0.14
Ash, % of DM	1.07	1.64	0.70	0.956	0.99	0.80	0.54
Starch, % of DM	-1.56	-13.67	9.67	5.987	0.99	0.26	0.04
ADF, % of DM	-0.44	0.30	-1.69	1.199	0.98	0.50	0.38
COD, % of DM	0.59	-0.46	0.16	0.579	0.98	0.63	0.27
pH	0.66	0.36	0.43	0.201	0.93	0.46	0.49
Plasma glucose, mg/dl	5.10	-3.36	7.44	6.773	0.99	0.82	0.28

Table 5. Influence of feed withdrawal and monensin feeding on animal weights, ruminal contents, and blood glucose.

	Withdrawal time, hours				Monensin, ppm		Probability, P <				
Measurements	0 h	24 h	36 h	SEm	0	33	Animal	Linear-Time	Quadratic-Time	Monensin	Time*Diet
Animal weight, kg	371.7	368	367.2	6.638	371.1	373.5	0.01	0.12	0.63	0.73	0.21
Ruminal contents											
Total weight, kg	40.41	30.34	35.73	2.070	35.76	35.23	0.01	0.05	0.02	0.80	0.84
Total weight, % of BW	10.57	8.16	9.70	0.570	9.57	9.39	0.04	0.14	0.02	0.17	0.98
Particulate matter, kg	18.08	7.21	5.24	6.637	10.25	10.09	0.01	0.01	0.04	0.84	0.93
Particulate, % of wet wt	43.89	23.60	15.28	1.466	27.95	27.23	0.01	0.01	0.52	0.63	0.96
Particulate DM, %	37.91	30.21	29.17	0.707	21.88	22.88	0.01	0.01	0.05	0.22	0.25
Imbibed liquid, % of liquid in rumen	33.67	18.99	11.43	1.775	21.41	21.32	0.01	0.01	0.95	0.96	0.75
Liquid, L	31.48	27.27	32.68	1.965	30.48	30.47	0.01	0.96	0.06	0.99	0.68
Dry matter, kg	8.94	3.07	3.06	0.464	5.28	4.76	0.01	0.01	0.01	0.28	0.54
Dry matter, % of BW	2.33	0.83	0.84	0.126	1.41	1.26	0.01	0.01	0.01	0.23	0.35
Rumen contents, % DM	21.77	10.41	8.66	0.929	14.29	12.94	0.01	0.01	0.96	0.17	0.31
Organic matter, kg	8.30	2.73	2.62	0.440	4.81	4.29	0.01	0.01	0.01	0.26	0.54
Ash, kg	0.33	0.11	0.13	0.040	0.18	0.20	0.01	0.01	0.10	0.54	0.85
Starch, kg	3.39	0.37	0.61	0.288	1.47	1.44	0.01	0.01	0.01	0.92	0.98
ADF, kg	2.17	1.03	0.81	0.118	1.45	1.22	0.02	0.01	0.13	0.08	0.74
COD, kg	7.57	3.54	2.65	0.619	4.71	4.46	0.02	0.01	0.35	0.69	0.78
Organic matter, % of DM	92.51	89.08	84.62	0.580	89.29	88.18	0.01	0.01	0.03	0.08	0.66
Ash, % of DM	3.38	3.81	3.68	0.548	3.16	4.10	0.20	0.65	0.74	0.11	0.81
Starch, % of DM	37.72	16.29	14.51	2.001	21.81	23.88	0.01	0.01	0.04	0.32	0.38
ADF, % of DM	24.00	30.49	29.02	1.918	29.32	26.36	0.67	0.05	0.21	0.15	0.78
COD, % of DM	85.70	100.89	100.99	6.419	93.90	97.85	0.31	0.09	0.54	0.55	0.72
pH	5.39	6.44	7.10	0.122	6.32	6.31	0.01	0.01	0.56	0.89	0.72
Plasma glucose, mg/dl	56.1	60.8	58.3	8.673	60.80	56.10	0.97	0.81	0.77	0.59	0.46

Table 6. Influence of feed withdrawal and monensin feeding on fractional rates of change in animal weight, ruminal contents, and blood glucose.

	Control	Monensin	Control	Monensin	Withdrawal time			Monensin, ppm		Probability, P <				
Fractional rate of change, %/h	24	24	36	36	0-24 h	24-36 h	SEm	0	33	Animal	Linear-Time	Quadratic-Time	Monensin	Time *Diet
Animal weight, kg	0.07	-0.49	-0.24	0.03	-0.21	-0.10	0.233	-0.16	-0.16	0.88	0.63	0.74	0.99	0.05
Ruminal contents														
Total weight, kg	-1.01	-0.72	0.67	1.04	-0.87	0.85	0.397	-0.18	0.16	0.01	0.14	0.01	0.74	0.97
Total weight, % of BW	-1.08	-0.23	0.91	1.00	-0.65	0.96	0.377	-0.02	0.32	0.01	0.16	0.01	0.73	0.74
Particulate matter, kg	-3.14	-2.75	-2.69	-2.49	-2.94	-2.59	0.415	-2.90	-2.64	0.08	0.69	0.02	0.75	0.92
Particulate DM, %	-2.13	-2.03	-3.37	-3.52	-2.08	-3.45	0.495	-2.73	-2.79	0.14	0.10	0.06	0.92	0.88
Imbibed liquid, % of ruminal liquid	-1.40	-2.09	-3.58	-3.48	-1.74	-3.53	0.570	-2.55	-2.72	0.14	0.06	0.61	0.84	0.67
Liquid, L	-0.15	-0.27	0.98	1.38	-0.21	1.18	0.427	0.37	0.60	0.02	0.22	0.02	0.82	0.82
Dry matter, kg	-4.45	-2.83	-1.77	-2.11	-3.64	-1.93	0.458	-2.95	-2.64	0.04	0.10	0.06	0.73	0.32
Dry matter, % of BW	-4.52	-2.34	-1.53	-2.14	-3.43	-1.84	0.604	-2.79	-2.48	0.12	0.14	0.05	0.75	0.17
Rumen contents, % DM	-3.44	-2.11	-2.44	-3.15	-2.78	-2.79	1.362	-2.77	-2.80	0.98	0.98	0.82	0.96	0.07
Organic matter, kg	-4.56	-3.00	-2.03	-2.50	-3.78	-2.26	0.472	-3.12	-2.92	0.06	0.13	0.06	0.82	0.28
Ash, kg	-7.98	-5.61	-3.74	-4.46	-6.79	-4.10	1.115	-5.60	-5.29	0.05	0.30	0.17	0.89	0.56
Starch, kg	-5.27	-2.01	-1.84	-2.52	-3.63	-2.18	0.906	-3.22	-2.59	0.09	0.42	0.03	0.71	0.27
ADF, kg	-2.67	-1.86	-0.89	-2.33	-2.26	-1.61	0.975	-1.59	-2.28	0.40	0.63	0.71	0.59	0.42
COD, kg	-2.71	-1.22	-0.65	-1.71	-1.96	-1.18	0.733	-1.46	-1.67	0.08	0.61	0.01	0.88	0.42
Organic matter, % of DM	-0.11	-0.16	-0.26	-0.39	-0.14	-0.32	0.053	-0.18	-0.28	0.17	0.02	0.14	0.13	0.63
Ash, % of DM	-0.81	0.83	-0.07	-0.41	0.01	-0.24	0.632	-0.28	0.04	0.03	0.88	0.54	0.83	0.56
Starch, % of DM	-3.52	-2.77	-1.98	-2.34	-3.15	-2.16	0.899	-2.66	-2.65	0.10	0.58	0.04	0.99	0.77
ADF, % of DM	1.78	0.98	0.88	-0.22	1.38	0.33	0.620	1.35	0.35	0.89	0.32	0.38	0.31	0.89
COD, % of DM	1.74	1.62	1.12	0.40	1.68	0.76	0.454	1.48	0.96	0.25	0.18	0.27	0.41	0.67
pH	0.44	0.28	0.45	0.56	0.36	0.51	0.119	0.43	0.44	0.42	0.37	0.49	0.91	0.41
Plasma glucose, mg/dl	0.82	9.00	2.76	-1.12	4.91	0.83	5.635	2.80	2.93	0.77	0.52	0.28	0.98	0.35

Table 7. Influence of feed withdrawal and corn processing on animal weight and ruminal contents.

	Fasting time												
	0 h	0 h	24 h	24 h		Probability, P <						P <	P <
Diet	HMC	SFC	HMC	SFC	SEm	Animal	0 h	24 h	Time	HMC	SFC	Diet	Time*diet
Animal weight, kg	388.8	391	385.2	388.3	5.331	0.01	389.9	386.8	0.56	387.0	389.7	0.63	0.93
Ruminal contents													
Total weight, kg	30.88	27.90	28.17	26.46	1.304	0.49	29.39	27.32	0.13	29.53	27.18	0.09	0.63
Total weight, % of BW	8.01	7.13	7.33	6.81	0.402	0.40	7.57	7.07	0.23	7.67	6.97	0.10	0.66
Particulate matter, kg	9.47	12.24	4.71	5.02	0.653	0.95	10.86	4.87	0.01	7.09	8.63	0.03	0.05
Particulate, % of wet wt	30.78	44.36	16.51	19.45	2.379	0.52	37.57	17.98	0.01	23.65	31.91	0.01	0.04
Particulate DM, %	23.75	28.37	21.49	21.21	0.622	0.15	26.06	21.35	0.01	22.62	24.79	0.01	0.01
Imbibed liquid, % of liquid in rumen	26.63	38.70	14.12	16.93	2.131	0.45	32.67	15.53	0.01	20.38	27.82	0.01	0.05
Liquid, L	27.21	23.01	25.95	24.01	1.252	0.48	25.11	24.98	0.92	26.58	23.51	0.03	0.38
Dry matter, kg	3.67	4.89	2.22	2.45	0.171	0.97	4.28	2.34	0.01	2.95	3.67	0.01	0.01
Dry matter, % of BW	0.95	1.25	0.57	0.63	0.047	0.47	1.10	0.60	0.01	0.76	0.94	0.01	0.01
Rumen contents, % DM	11.92	17.70	7.86	9.40	0.396	0.40	14.81	8.63	0.01	9.89	13.55	0.96	0.02
Organic matter, kg	3.01	4.27	1.73	1.83	0.153	0.94	3.64	1.78	0.01	2.37	3.05	0.01	0.01
Ash, kg	0.65	0.63	0.49	0.62	0.034	0.45	0.64	0.56	0.02	0.57	0.63	0.14	0.03
Starch, kg	0.62	1.81	0.12	0.24	0.066	0.17	1.22	0.18	0.01	0.37	1.03	0.01	0.01
COD, kg	4.66	5.81	2.60	2.94	0.264	0.81	5.24	2.77	0.01	3.63	4.38	0.01	0.14
Organic matter, % of DM	81.80	87.22	78.04	74.79	0.888	0.36	84.51	76.42	0.01	79.92	81.01	0.24	0.01
Ash, % of DM	18.20	12.78	21.96	25.20	0.888	0.36	15.49	23.58	0.01	20.08	18.99	0.24	0.01
Starch, % of DM	16.81	37.00	5.70	9.75	1.218	0.02	26.91	7.73	0.01	11.26	23.38	0.01	0.01
COD, % of DM	127.00	118.66	118.52	120.45	6.032	0.79	122.83	119.49	0.59	122.76	119.56	0.60	0.41
pH	5.38	5.43	6.92	7.12	0.105	0.62	5.41	7.02	0.01	6.15	6.28	0.22	0.50

Table 8. Influence of feed withdrawal and corn processing on fractional rates of change in animal weight and ruminal contents.

Fractional rate of change, %/h	0-24 h period	Sem	P < Animal	HMC	SFC	P < Diet
Animal weight, kg	-0.07	0.131	0.53	-0.07	-0.06	0.95
Ruminal contents						
Total weight, kg	-0.64	0.495	0.73	0.84	2.65	0.65
Total weight, % of BW	-0.60	0.464	0.72	-0.74	-0.45	0.68
Particulate matter, kg	-6.80	1.038	0.19	-6.06	-7.54	0.36
Particulate, % of wet wt	-6.20	0.918	0.68	-5.32	-7.08	0.72
Imbibed liquid, % of ruminal liquid	-6.28	0.764	0.12	-5.46	-7.09	0.19
Liquid, L	-0.01	0.432	0.60	-0.36	35.00	0.30
Dry matter, kg	-4.99	0.829	0.59	-4.18	-5.79	0.23
Dry matter, % of wet weight	-4.92	0.549	0.32	-4.11	-5.73	0.06
Dry matter, % of BW	-4.39	0.876	0.69	-3.44	-5.33	0.06
Rumen contents, % DM	-4.39	1.112	0.98	-3.44	-5.33	0.06
Organic matter, kg	-5.82	0.905	0.59	-4.57	-7.07	0.11
Ash, kg	-1.31	0.903	0.69	-2.56	-0.05	0.11
Starch, kg	-15.94	0.809	0.05	-14.36	-17.52	0.04
COD, kg	-5.24	1.017	0.83	-4.79	-5.69	0.01
Organic matter, % of DM	-0.84	0.167	0.74	-0.39	-1.28	0.01
Ash, % of DM	2.06	0.654	0.52	-1.62	5.74	0.01
Starch, % of DM	-10.96	0.912	0.04	-10.17	-11.74	0.28
COD, % of DM	-0.26	0.387	0.18	-0.61	0.10	0.25
pH	1.62	0.159	0.44	1.54	1.69	0.55

Table 9. Loss of weight, and wet, dry, and organic matter and COD at 24 hours after the last meal as a percent of that in the rumen immediately after feeding.

	Trial			Weighted
	1	2	3	Mean
Live weight	2.61	4.91	1.67	2.98
Wet matter	20.00[a]	18.84[a]	14.24[b]	18.11
Dry matter	44.72[b]	58.25[a]	69.80[a]	55.25
Organic matter	46.99[b]	59.63[a]	75.26[a]	58.15
Starch	90.50[a]	58.15[b]	97.82[a]	83.67
ADF	45.70	41.86	ND	44.26
COD	43.78[b]	37.52[c]	71.56[a]	49.65

ND = not determined.

CHAPTER IV

IMPACT OF WITHHOLDING FEED ON PERFORMANCE AND CARCASS MEASUREMENTS OF FEEDLOT STEERS

Abstract

To determine how live weight, shrink, and carcass measurements change during fasting, feed was either not withheld or withheld for 24 hours prior to transit of steers to the packing plant. Three pens with about 190 steers per pen were subjected to each treatment. Withholding feed saved one day's feed cost but decreased live and carcass weights of steers by about 12%. Surprisingly, dressing percentage was increased only slightly. Marbling scores were not reduced by withholding feed. Incidence of carcasses with lean classified as fully dark cutting was nearly tripled by withholding feed. Economically, the reduced carcass weight and higher dark cutting incidence outweigh current advantages for withholding feed that can reduce the costs for feed and waste disposal.

(Key words: Feed withdrawal, Carcass measurements, Dark cutting beef.)

Introduction

Although the quantity of organic matter present in the rumen can be reduced by withholding feed from cattle prior to harvest, feed withdrawal may have adverse effects on carcass weight or quality. Surprisingly little information is available on the impact of feed withdrawal on carcass characteristics. One study of feed withdrawal, conducted over 20 years ago by researchers at Kansas State University (Carr et al., 1969), detected no reduction in carcass quality using a feed withdrawal period of up to 48 hours.

However, the number of steers (25 steers per treatment) in that study was limited for appraising carcass quality effects. Feed withdrawal never became popular commercially because in the past most cattle were sold on a live weight basis and feed withdrawal usually reduces live weight. With more cattle today being sold on a carcass weight instead of a live weight basis, and with more cattle being purchased by the packing plant up to 7 days prior to delivery, live weight could be measured before feed withdrawal. To meet formula specifications, some feedlots withhold feed in an attempt to increase dressing percentage. Feed withdrawal should have appeal to packing plants because the quantity of organic matter and chemical oxygen demand of ruminal contents is reduced by feed withdrawal (Janloo et al., 1998). The objective of this study was to determine the impact of withholding feed for 24 hours on live and carcass characteristics of steers. To obtain adequate numbers of cattle to detect small differences, large pens of feedlot steers from a cooperating commercial feedyard were used.

Materials and Methods

Because a large number of cattle were needed for this research, effects of feed withdrawal on carcass merit was accomplished thanks to extensive cooperation from a cattle feeding facility (Circle E Feedlot, Potlin, KS) and a processing plant (Excel Corporation, Dodge City, KS). Effects of feed withdrawal for a 24-hour period on 1) carcass weight and 2) economically important carcass and meat quality traits were measured using 6 pens of finished steers (1138 steers). Steers having similar background and feedlot history were marketed on consecutive weeks during November and December. On alternate weeks, feed was either withdrawn for 24 hr or not withdrawn prior to transporting the steers to the packing plant. Live weights were measured at the time cattle were loaded onto trucks and after unloading from these trucks upon arrival at the packing plant approximately 320 km away. Weight loss (shrink) during transport, hot carcass weights, marbling scores, and dark cutting incidence were determined.

Results and Discussion

Results are presented in Table 10. Based on feedlot records, mean feedlot entry weight averaged 2.96 kg less for steers marketed during the weeks that feed was withdrawn prior to slaughter. Final full weight was 10.83 kg less for these cattle. The difference was less (6.62 kg) at arrival at the packing plant but remained at 4.26 kg in carcass weight. Using a mean dressing percentage of 63.68%, the live weight difference at slaughter should have been 6.71 kg, quite close to the difference in weight at arrival (6.62 kg) at the packing plant. This means that total feedlot weight gain (live basis) probably was approximately 3.76 kg less (6.71 minus 2.94) for groups of cattle that had feed withdrawn. This equates to 2.4 kg in carcass weight. At $1 per .454 kg carcass weight (or $64/cwt. live weight), this is equivalent to $5.30 less return from cattle that had feed withdrawn 24 hours prior to marketing.

Transit shrink was lower for cattle that had feed withdrawn prior to marketing. Dressing percentage, calculated from a 4% pencil shrunk final feedlot weight, tended to be greater with feed withdrawal when calculated based on feedlot shrunk weight but not when based on plant arrival weights. The difference based on feedlot shrunk weight (63.9 vs 63.5%) was not as large as producers may presume. Although the 6.71 kg difference in arrival weight at the slaughter plant (1.3%) certainly is partly due to reduced gut fill, the lower carcass weight of cattle subjected to feed withdrawal implies that withholding feed results in a substantial loss of carcass weight (2.4 kg or 0.8%).

Live weight loss of cannulated cattle during a 24 hour feed withdrawal period ranged from 0 to 9.07 kg (0 to 3.4% for a mean of about 3% or 11.34 kg) with decreased weight of wet ruminal contents being responsible for only about half (mean of 5.44 kg) of this weight loss (Janloo et al., 1998). Because water tends to replace dry matter that disappears from the rumen during fasting, withholding water probably would increase dressing percentage more than simply withholding feed. A loss of 1.1 kg of carcass tissue per animal would not be expected to occur in 24 hours (Table 10). This suggests that this carcass weight loss must be attributable partly to reduced retention of fluids in tissues. Reduced fluid retention could be due to decreased concentrations of intracellular ions and glycogen. Glycogen is stored in tissue with about 6 times its weight of water so a decrease in muscle glycogen from 1% to 0.7% could account for a carcass weight loss of 2.1% (1.8% + 0.3%) of muscle weight; this would equal 0.84% of a carcass that is 40% muscle or 2.54 kg from a 317.5 kg carcass. This supports the concept that reduced glycogen and water retention in muscle alone might account for the loss in carcass weight with feed withdrawal observed in this study.

Withholding feed for the final 24 hours reduced total feed intake over the final 5 days by 9.16 kg per steer, roughly equal to the amount of feed fed in one day. At a cost of $170 per ton of feed, this would result in a savings of $1.72 per steer.

Carcass grade and yield grade both tended to increase with feed withdrawal. Although these changes were not significant statistically, these increases might reflect a slight decrease in retention of fluid in muscle. Although the total incidence of all classes of dark cutters was not altered significantly, the incidence of full dark cutting carcasses was nearly tripled (1.04 vs .35%) by feed withdrawal. This again may be one consequence of loss of muscle glycogen during the feed withdrawal period. Though not significant statistically, such an increase represents a substantial economic penalty from feed withdrawal. With a $35/cwt. penalty for dark cutting carcasses, this increase prorated among all animals represented a loss of about $1.80 per animal fed in this study. Ignoring the slight increase in quality grade associated with feed withdrawal, the total cost associated with feed withdrawal equals about $7.10 per animal ($5.30 for reduced carcass weight + $1.80 for more dark cutters).

Savings from feed withdrawal would include a feed savings discussed earlier of $1.72 per steer and a potential slight reduction in transport cost. With 10.9 kg less weight to transport, perhaps one more finished steer could be transported per semi-truck; if trucking charge is based on cattle weights, trucking cost might be reduced by 2% by withholding feed for 24 hours. If transit distance were 320 km and cost per loaded mile were $2, this savings would equal about $8 per load or, if 40 steers were hauled, $0.20 per animal if the truck were loaded to capacity or if the trucking charge were based on weight, not simply on mileage.

Overall, these figures indicate that carcass penalties to the cattle feeder and packing plant from feed withdrawal overshadow the potential savings in feed and trucking. For every steer withheld from feed for 24 hours prior to transport, the beef industry probably loses about $5 ($7.10 - $1.72 - $0.20).

Implications

Withholding feed for 24 hours prior to harvest decreased live and carcass weights of finished steers by about 12% and doubled the incidence of dark cutting beef carcasses. Although the amount of organic matter that must be handled could be cut in half by withholding feed for this time period, it is unlikely that the reduction in the amount of waste at packing plants would counterbalance the economic losses associated with reduced carcass weight and value.

Table 10. Effects of feed withdrawal prior to marketing on steer weights and feed intakes.

Feed withdrawal time, hr	0	24	Difference		Probability
			Numeric	%	P <
Cattle, No.	563	575			
Pens, No.	3	3			
Mean weight, kg.					
Initial into feedlot	316.3	313.3	-3.0	-0.93	0.64
Final full, feedlot exit	555.1	544.3	-10.8	-1.95	0.94
Final, shrunk 4%	532.9	522.5	-10.4	-1.96	0.25
Arrival at packing plant	541.5	534.8	-6.7	-1.22	0.43
Hot carcass	338.1	333.9	-4.2	-1.26	0.38
Daily gain, kg.	1.25	1.21	-0.04	-3.26	0.19
Feed intake, kg./head					
Last 5 days	50.4	41.3	-9.1	-18.2	0.08
Last day	6.8	0.23	-6.57	-96.69	0.01
Transit shrink, %	2.46	1.73	-0.73	-29.67	0.03
Dressing percentage					
Of shrunk lot weight	63.46	63.90	0.44	0.69	0.10
Of plant arrival weight	62.45	62.430	-0.02	0.00	0.99

Table 11. Effects of feed withdrawal prior to marketing on carcass characteristics of feedlot cattle.

Feed withdrawal time, hr	0	24	Numeric Difference	Percentage Difference	Probability P <
Marbling score	412	425	13.0	3.16	0.39
USDA Quality grade	3.37	3.59	0.22	6.53	0.17
USDA Quality class					
Prime, %	1.24	1.22	-0.02	-1.61	0.95
Premium choice, %	14.25	17.85	3.60	25.26	0.38
Low choice, %	31.84	34.73	2.89	9.08	0.56
Select, %	49.29	44.95	-4.34	-8.81	0.60
Standard, %	3.39	1.07	-2.32	-68.44	0.11
Lean maturity	151	155	4.0	2.65	0.38
A maturity, %	98.05	97.42	-0.63	-0.64	0.78
B maturity, %	1.95	2.58	0.63	32.31	0.78
Dark cutting carcasses					
All types, %	1.68	1.75	0.07	4.17	0.84
Full dark, %	0.35	1.04	0.69	197.14	0.11
Blood splash, %	1.61	2.26	0.65	40.37	0.52
KPH percentage	1.76	2.00	0.24	13.64	0.31
Fat thickness, cm.	1.27	1.34	0.03	6.00	0.27
Ribeye area					
cm^2	91.7	91.7	-0.01	0.0	0.99
cm^2/cwt.	27.1	27.5	0.4	1.48	0.71
Yield grades					
Preliminary	3.16	3.23	0.07	2.22	0.31
Adjusted preliminary	3.24	3.34	0.10	3.09	0.27
USDA Yield Grade	2.41	2.58	0.17	7.05	0.15
Calculated	2.38	2.49	0.11	4.62	0.67
USDA YG >3, %	4.11	5.27	1.16	28.22	0.68

CHAPTER V

CHARACTERISTICS OF DARK CUTTING STEER CARCASSES

Abstract

To determine how carcasses with various degrees of lean darkness differ, standard carcass measurements were obtained from 1129 steers. Of these carcasses, 2.8% had some degree (1/3, 2/3, or full classifications) of dark cutting lean with 0.7% being classified as full dark cutters. Though hot carcass weight did not differ with lean color, the greater the degree of darkness of lean, the greater ribeye area and less the fat thickness over the rib and the lower the yield grades. These differences suggest that cattle with greater leanness are more susceptible to darker colored lean. USDA quality grade tended to be lower with darker lean, especially for full dark cutting carcasses for which carcass grades are discounted because of the dark colored lean. Because of their greater cutability, carcasses classified as having fully dark lean, price discounts for dark cutting carcasses may be excessive, particularly considering that processed and cooked meats from dark cutting carcasses supposedly are fully acceptable in terms of tenderness, juiciness, and flavor by consumers.

(Key words: Carcass measurements, Dark cutting beef.)

Introduction

Specific management or harvest techniques that increase energy expenditures and decrease glycogen content of muscle have been associated with an increased prevalence of carcasses having lean that is dark rather than bright cherry red in color. Withholding feed and other factors such as warm days and cool nights, specific implants, gender, longer transport time, crowded transport conditions, longer lairage time, and wild temperament have been implicated as increasing the prevalence of dark cutting carcasses (Scanga and Belk, 1998). In Europe, the incidence of dark cutting carcasses often exceeds 30% compared to means in the U.S. of about 5 and 2% in 1992 and 1995, respectively, based on Beef Quality Audits (NCBA, 1992; 1995) or only 0.24% based on a survey of nine commercial feedyards (Scanga and Belk, 1997). A seasonal effect, with a higher incidence noted in spring and especially in late fall, may explain the divergence of the two means from the U.S. The higher incidence in Europe has been attributed to longer transport and lairage times and greater physical activity and fighting between bulls that have been raised in smaller pens than steers raised in larger groups in the US. Depending on the degree of darkness of the color of lean tissue, carcasses are classified as 1/3, 2/3 or fully dark cutting. Carcasses classified as fully dark cutting are discounted in quality grade, and, because the dark color is less appealing in the supermarket display case, price typically is discounted by about 30%. To determine how those carcasses with dark cutting lean differed from carcasses with bright cherry red lean, we contrasted carcass measurements of market steers with cohort animals of similar background and fed in the same feedlot pen.

Materials and Methods

Finished steers (n = 1136; mean weight = 549.6 kg.) were marketed on six different dates. Each pen of steers (about 190 per pen) had been fed together for at least 200 days prior to harvest. On alternate weeks, feed was either withdrawn for 24 h or not withdrawn prior to transporting the steers to the packing plant. Live weights were measured at the time that cattle were loaded onto trucks and off these trucks upon arrival at the processing facility approximately 320 km away. Following harvest, carcasses were chilled at 0°C for approximately 36 hours, after which USDA quality and yield grade (USDA, 1997) carcass characteristics as well as weight loss (shrink) were collected. Carcass measurements from steers with various degrees of dark cutting lean tissue were contrasted statistically.

Results and Discussion

Measurements for carcasses classified as 1/3, 2/3 and fully dark cutting are contrasted with carcasses from cattle in the same pen that had a bright cherry red color in Table 12. This comparison should be less biased than simply calculating means of carcass measurements for all the dark cutting carcasses in a packing plant because pens of cattle with a high dark cutting incidence may differ in background and carcass measurement from normal cattle. The total number of dark cutting carcasses is not large, although 2.8% of cattle in this sample had some degree of dark cutting with 0.7% being classified as full dark cutters.

No differences in mean carcass weight were detected. This is surprising based on the suggestion that two factors often associated with dark cutters, nervousness and extensive muscling, would be expected to cause carcass weights to be less or greater, respectively, than other cattle fed in the same pen. Of carcasses classified as full dark cutters, one had a carcass weight of 287.1 kg, more than one standard deviation lower than control cattle (336 $\pm$ 31.7 kg), but the other 7 had carcass weights (range = 319.7 to 346.0 kg) that fell within the expected weight range. One dark cutting carcass had a calculated yield grade of 0.75, but yield grades of others ranged from 1.3 to 2.2. Consequently, carcass characteristics of dark cutting cattle did not reflect certain characteristics that have been associated previously with an elevated incidence of dark cutting cattle within a specific group or pen. Considering the numerous factors that have been associated with dark cutting carcasses, perhaps two or more subgroups of cattle may become dark cutters. A small percentage of animals may have physiological abnormalities that cause this condition while additional animals may become dark cutters when subjected to unusual or abnormal environmental or stress conditions. This would suggest that stress avoidance and increasing energy reserves prior to harvest might reduce but not fully eliminate this malady.

Carcasses of cattle classified as dark cutting tended to be leaner (larger ribeye area that, when combined with less external fat, resulted in numerically lower (more desirable) yield grades) than carcasses with brighter lean color. A greater incidence of dark cutting carcasses in recent years than decades ago may be due to a higher incidence among cattle selected for greater leanness at a specified weight. Implants that increase lean mass might increase dark cutting incidence by a similar mechanism. Altering type of muscle fibers, i.e., increasing the prevalence of white, non-oxidative fibers, could increase rate of glycogen depletion during fasting, exercise, or excitement. USDA yield grades tended to underestimate true yield grades, particularly for fully dark cutting carcasses. Marbling scores also tended to be lower for dark cutting carcasses, but no difference in carcass bone maturity was detected. The percentage of carcasses in the lower USDA quality grades (select and standard) was greater for dark cutting carcasses due to lower marbling scores of 1/3 and 2/3 dark carcasses; this was particularly apparent for fully dark carcasses, presumably due to the mandated USDA grade discount. This mandated grade discount may represent overkill with regard to tenderness and eating quality of lean beef from dark cutting carcasses. Although meat characteristics were not measured in this trial, fabrication is thought to yield cooked products fully as acceptable to consumers as fresh beef that has a bright red color.

Implications

Carcasses of steers that had very dark colored lean were more muscular but had less external fat and marbling and lower numerical yield grades than those with bright cherry red lean. No differences in carcass weights were detected that would support the contention that specific factors known to elevate the incidence of dark cutters above a normal rate, e.g., nervousness or large framed or continental breeds, were responsible for the dark cutting when its incidence is rather low. Results support the concept that multiple factors probably are responsible for dark cutters, and that improved cattle management may reduce but not completely eliminate dark cutters.

Table 12. Least squares means of carcass measurements of dark cutting steers as compared to carcass measurements of other steers fed in the same pen.

Measurement	Dark cutting score				Probabilities, P <		
	0	1/3	2/3	Full	Effects	All vs. 0	Full vs. 0
Cattle, number	1106	20	3	8			
Hot carcass weight, kg	366	327	337	328		.48	.49
Rib eye area							
cm^2.	91.6a	93.5ab	96.8ab	99.4b	LC	.06	.02
cm^2/cwt.	25.0a	28.61^{ab}	28.7ab	30.3b	LC	.08	.01
Marbling score	420^{d}	399de	409de	356^{e}		.17	.06
KPH, %	1.89	1.79	1.82	1.70		.15	.12
Blood splash, %	1.98	.34	.30	-.27 ^{e}		.57	.64
Rib fat, cm.	1.32^{a}	1.09^{b}	1.16^{ab}	.84^{b}	LC	.01	.01
Yield grades							
Preliminary	3.20^{a}	3.01^{b}	3.02^{ab}	2.71^{b}	LC	.01	.01
Adjusted	3.29^{a}	3.08^{b}	3.14^{ab}	2.81^{b}	LC	.01	.01
Actual	2.45^{a}	2.02^{b}	2.18^{ab}	1.49^{b}	LC	.01	.01
USDA	2.49	2.34	2.24	2.57		.64	.81
USDA YG>3,%	4.81	.02	.69	.29		.37	.54
Quality grades							
USDA	3.48^{a}	3.11^{b}	3.03^{ab}	3.91^{ab}		.67	.43
Prime, %	1.3	.2	0	0		.64	.73
High choice, %	16.3	11.5	3.5	-2.1 ^{e}		.17	.16
Low choice, %	33.5	26.9	37.8	10.3		.45	.17
Select, %	46.8	51.3	60.2	78.3		.16	.07
Standard, %	2.0^{b}	10.2^{a}	-1.4^{ab}	13.5^{ab}	c	.12	.03
Bone maturity							
A class, %	97.7	100.1	99.2	100.1		.55	.65
B class, %	2.3	-.2 ^{e}	.8	-.1 ^{e}		.55	.65

$^{a, b}$ Means not sharing a superscript differ ($P < .05$).

$^{c, d}$ Means not sharing a superscript differ ($P < .10$).

Letters imply responses to dark cutting score (l = linear effect at $P < .05$; L = linear effect at $P < .01$; c = cubic effect at $P < .05$; C = cubic effect at $P < .01$.

^{e} Negative least squares means are not significantly different from zero.

Fig. 1 Effect of Feed Withdrawal on Mass in Rumen

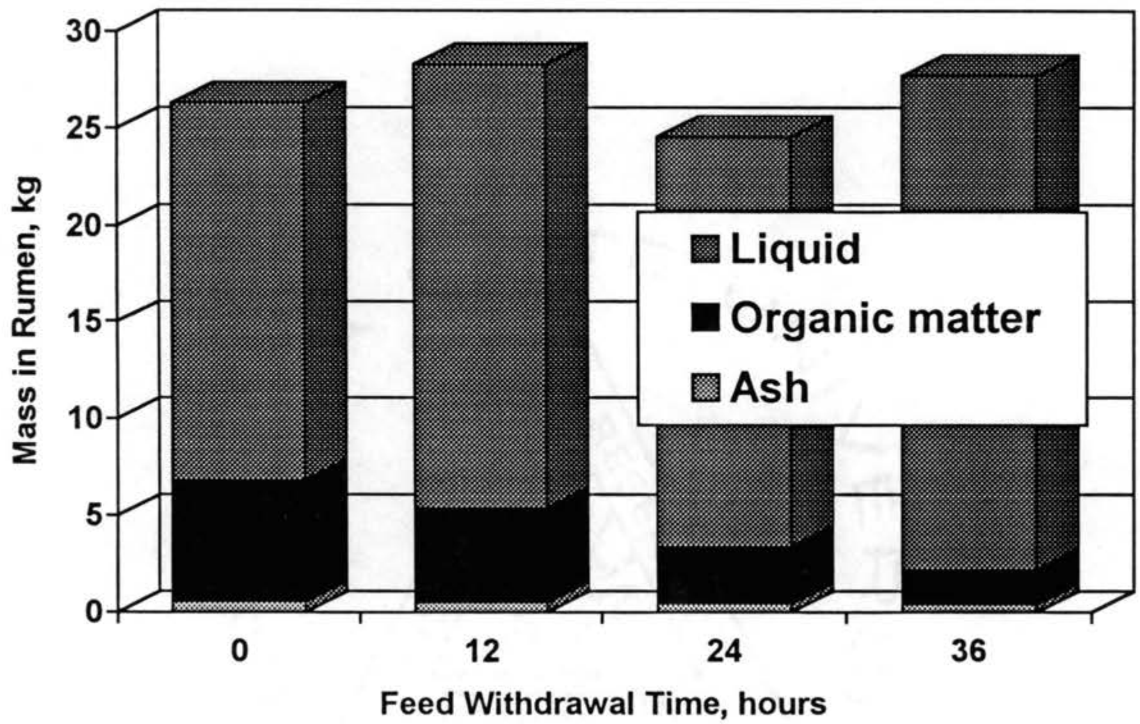


Fig. 2 Rate of Disappearance of Organic Matter, Fiber, and COD in the Rumen

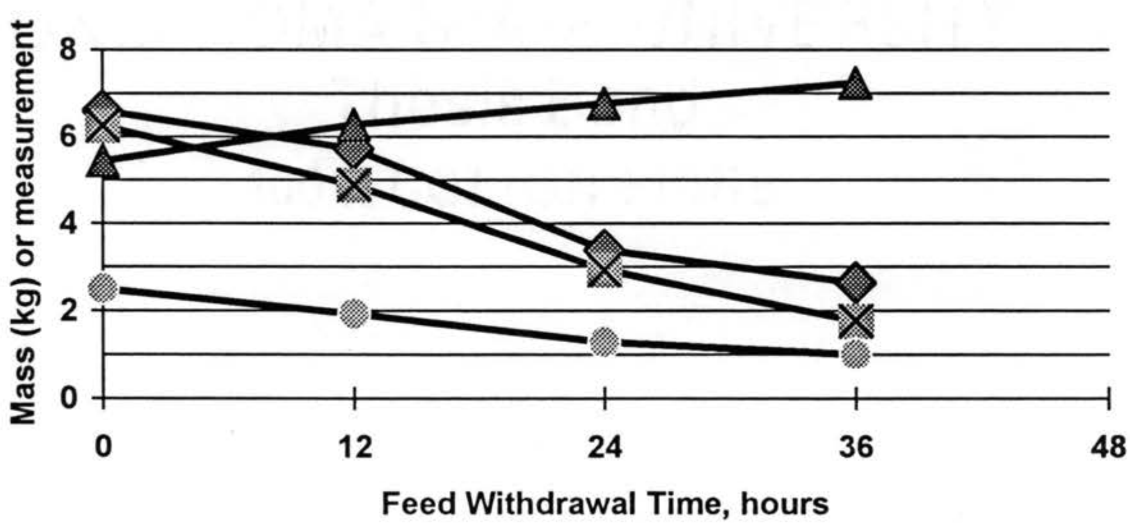


Fig. 3 Dry Weight in Rumen

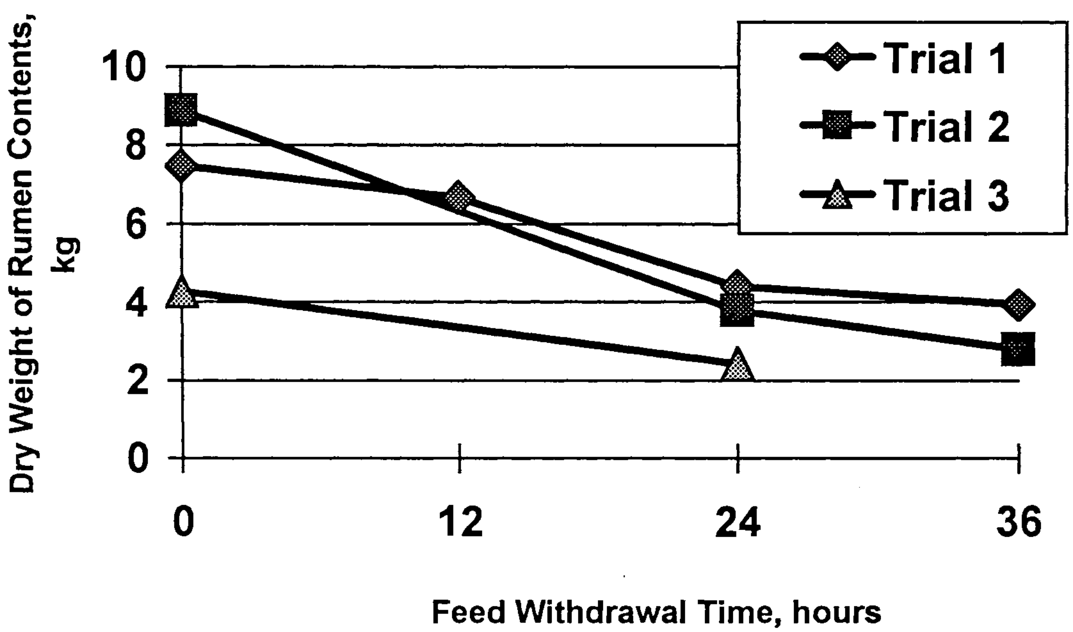


Fig. 4 Organic Matter in the Rumen

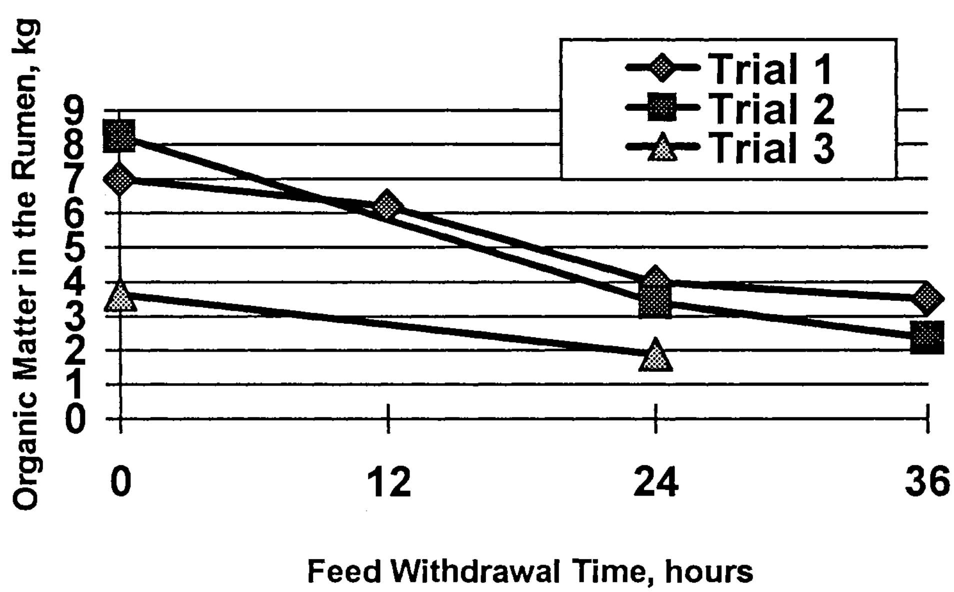
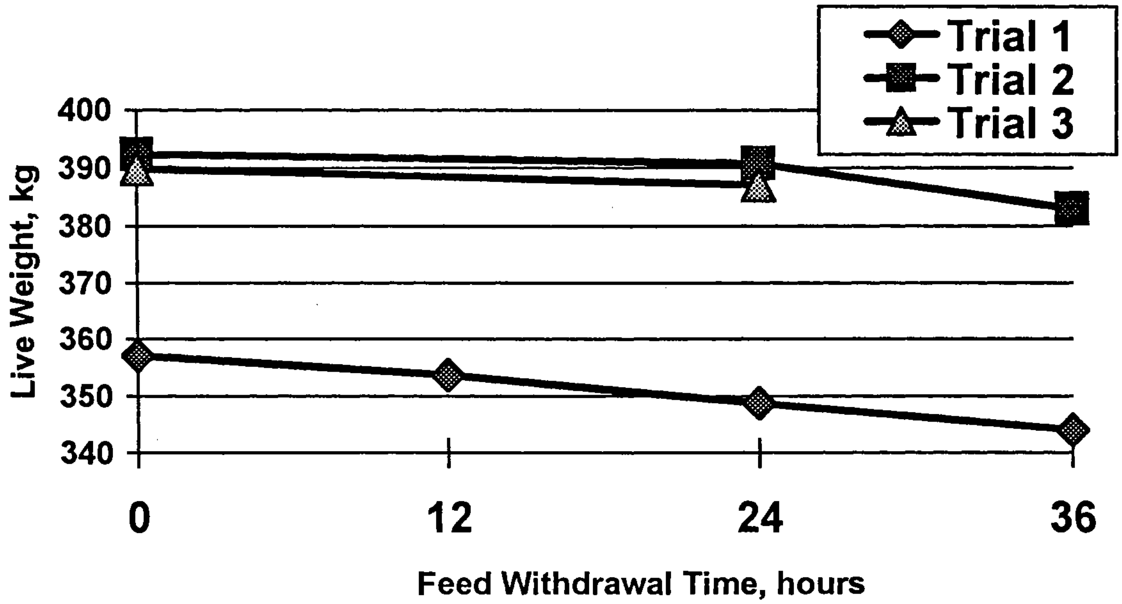


Fig. 5 Live Weights



LITERATURE CITED

AOAC. 1975. Official Methods of Analysis (12th edn.). Association of Official Analytical Chemists, Washington, D.C.

American Public Health Association, et. al. 1985. Standards Methods for Examination of Water and Wastewater. 16th edn. APHA, AWWA, WPCF.

Bailey, C.B. 1961. Saliva secretion and its relation to feeding in cattle. 3. The rate of secretion of mixed saliva in the cow, during eating, with an estimate of magnitude of the total daily secretion of mixed saliva. Brit. J. Nutr. 15: 443-451.

Bond, J. and T.M. Rumsey and B.T. Weinland. 1976. Effect of deprivation and reintroduction of feed and water on the feed and water behavior of beef cattle. J. Anim. Sci. 43:873-878.

Carr, T., and D. Allen, P. Par and R. Cox. 1969. Effect of Pre-slaughter Withdrawal from Feed on Cattle Fasted for Varying Lengths of Time. KSU Cattl. Day, Rep. Of Progress 529:51.

Cole, N. A., and D. P. Hutcheson. 1981. Influence on beef steers of two sequential short periods of feed and water deprivation. J. Anim. Sci. 53(4): 907-915.

Conneely, D. and M. Gibbs. 1997. The Ruminant Livestock Efficiency Program Annual Conference Proceedings, August.

Dinius, D.A., M.E. Simpson and P.B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42:229.

Dubowski, K.M. 1962. An o-toluidine method for body-fluid glucose determination. Clin Chem 8:215.

Fernandez, G., G. Monin, J. Culioli, I. Legrand and Y. Quilichini. 1996. Effect of Duration of Feed Withdrawal and Transportation Time on Muscle Characteristics and Quality in Friesian-Holstein Calves. J. Anim. Sci. 74:1576-1583

Garza, J.D.D. 1990. Water kinetics in the rumen of beef cattle. Oklahoma State Univ. PhD dissertation.

Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). Agric. Handbook No. 379, USDA, ARS.

Gracey, J.F. 1986. 1986. Meat Hygiene. 8th edn. Bailliere Tindall, London.

Hicks, R. B., F. N. Owens and D. R. Gill. 1989. Behavioral patterns of feed lot steer. OK Agric. Exp. Sta. MP-127:94.

Janloo, S., H.G. Dolezal, B.A. Gardner, F.N. Owens, J. Peterson and M. Moldenhauer. 1998. Impact of withholding feed on performance and carcass characteristics of feedlot steers. Anim. Sci. Res. Rep. Okla. Exp. Sta. P-965.pp. 109-113.

Janloo, S., H.G. Dolezal, B.A. Gardner, C. Strassia, W. Clarkson, F.N. Owens and A. La Manna. 1998. Impact of withholding feed on weight and composition of ruminal contents. Anim. Sci. Res. Rep. Okla. Exp. Sta. P-965.pp. 114-120.

Jeremiah, L.E. and J.A. Newman, A.K. Tong and L.L. Gibson. 1988. Meat Sci., 22:83.

Johnson, K.A., and D.E. Johnson. 1995. Methane emissions from cattle. J. Anim. Sci. 73:2483-2492.

Jones, S.D.M., A.L. Schaefer, W.M. Robertson and B.C. Vincent. 1989. The Effects of Withholding Feed and Water on Carcass Shrinkage and Meat Quality in Beef Cattle. Meat Science 0309-1740. Elsevier Science Publishers Ltd., England. Printed in Great Britain.

Kauflin, V.R., H.B. Hedrick and W.C. Stringer. 1969. Effects of pre-slaughter feeding regimen on beef carcass characteristics. Research Bull. 953. Univeresity of Missouri-columbia, College of Agriculture, Agricultural Experiment Station.

Kenny, F.J., and P.V. Tarrent. 1984. Meat quality in beef heifers slaughtered at oestrus. Proc. 30th Euro. Meat Workers Meeting. Bristol, U.K. pp 99-100.

Kreikemeier, K. K., J.A. Unruh and T.P. Eck. 1990. Factors affecting the occurrence of dark cutting beef and selected carcass traits in finished beef cattle. Kansas Agric. Exper Sta. Report of Progress 1997, 794:1

Lemanager, R.P., F.N. Owens, B.J. Shockey, K.S. Lusby and R. Totusek. 1978. Monensin effects on rumen turnover rates, twenty four hour VFA patterns, nitrogen components and cellulose disappearance. J. Anim. Sci. 47:225.

MacFarlane, W.V. 1976. Water and electrolytes in domestic animals. In: Veterinary Physiology chapter 19. Ed. J. W. Phillis, W.B. Saunders Co. Philadelphia, U.S.A.

MacRae, J.C., and D.G. Armstrong. 1968. Enzyme methods for determination of alpha-linked glucose polymers in biological materials. J. Sci. Food Agric. 19:578.

Makela, A. 1956. Studies on the question of bulk in the nutrition of farm animals with special reference to cattle. Suomen Maataloustieteellisen Seuran Jaulkaisuja. 85:7

McVeigh, J.M., and P.V. Tarrant. 1983. J. Anim. Sci. 56:71.

Mitchell, G., J. Hattingh, and M. Ganhao. 1988. Stress in cattle assessed after handling, after transport and after slaughter. Veterinary record 123: 201-205

NRC. 1984. Nutrient Requirements of Beef Cattle. National Research Council – National Academy of Science, Washington, D.C.

National Cattlemen's Association. 1992. The National Beef Quality Audit. NCBA, Denver, Co.

National Cattlemen's Association. 1995. The National Beef Quality Audit. NCBA, Denver, Co.

Owens, F.N., D.S. Secrist, W.J. Hill and D.R. Gill. 1998. Acidosis in cattle a review. J. Anim. Sci. 76:275-286.

Owens, F.N., and A.L. Goetsch. 1986. Digesta passage and microbial protein synthesis. In: Control of Digestion and metabolism in ruminants. L.P. Milligan, W.L. Grovum, and A. Dobson, eds. A Reston Book, Prentice Hall, Englewood Cliffs, New Jersey.

Owens, F.N. and A.L. Goetsch. 1993. Ruminal fermentation. In: D.C. Church ed. The ruminant animal digestive physiology and nutrition. Prentice Hall Inc. pp.172-201

Poutiainen, E. 1968. Factors influencing the flow of fluid saliva and some cations through the reticulo omasal orifice of the cow. Ann. Agric. Fenn. 7(26):7

Price, J.F. and B.S. Schweigert. 1978. The Science of Meat and Meat Products. Food & Nutrition Press, Inc., Westport, CT.

Reid, C.S. 1965. Quantitative studies of digestion in the reticulo-rumen. I. Total removal and return of digesta for quantitative sampling in studies of digestion in the reticulo rumen of cattle. New Zeland Soc. Anim. Prod. Proc. 25:65.

Rigby, C.E., J.R. Pettit, M.F. Baker, A.H. Bentley, M.O. Salomons and H. Lior. 1980. Sources of salmonellae in an uninfected commercially processed broiler flock. Can. J. Comp. Med. 44:267-274.

SAS. 1985. SAS User's guide: Statistics. SAS Inst., Inc., Cary, NC.

Scanga, J.A., and K.E. Belk. 1998. Managing dark cutters in the feedlot. Southwest Nutrition Conference, University of Arizona, Tucson. pp. 61-70.

Schelling, G.T. 1984. Monensin mode of action in the rumen. J. Anim. Sci. 58:1518-1527.

Smith, G.C., J.W. Savell, H.G. Dolezal, T.G. Field, D.R. Gill, D.S. Hale, J.B. Morgan, S.L. Northcutt and J.D. Tatum. 1995. The final report of the national beef quality audit. Colorado State Univ., Fort Collins, Texas A&M Univ., College Station, and Oklahoma State Univ., Stillwater. NCA, Englewood, Co.

Streeter, M. N. 1982. Influence of Sorghum Grain Hybrid and Corn on Site and Extent of Digestion in Beef Steers.

Strictlin, W. R. 1986. Some factors affecting feed patterns of beef cattle; in Feed Intake by Beef Cattle, OK State Agric. Exp. Sta. MP:121-314.

Summers, J.D., and S. Leeson. 1979. Comparison of feed withdrawal time and passage of gut contents in broiler chickens held in crates or litter pens. Can. J. Anim. Sci. 59:63-66.

Tamminga, S. 1996. A review on environmental impacts of nutritional strategies in ruminants. J. Anim. Sci. 74:3112-3124.

Teeter, R.G. 1981. Indigestible markers; methodology and application in ruminant nutrition. Oklahoma State University. PhD dissertation.

Thornton, J. H., and F. N. Owens. 1981. Monensin supplementation and in vivo methane production by steers. J. Anim. Sci. 52:628.

Towne, G., T. G. Nagaraja, C. Owensby, and D. Harmon. 1986. Ruminal evacuation's effect on microbial activity and ruminal function. J. Anim. Sci. 62(3):783-788.

USDA. 1997. Official United States Standards for Grades of Carcass Beef. AMS-USDA, Washington, D.C.

Van Nevel, C.J., and D.I. Demayer. 1977. The effect of rumensin on some rumen fermentation parameters. Ann. Reech. Vet. 10:338.

Van Soest, P.J. 1985. Composition, fiber quality, and nutritive value of forage. Ames, Iowa, U . S . A . : Iowa State University press, 1985. P. 412-421.

Varel, V.H., and A.G. Hashimoto. 1981. Effect of Dietary Monensin or chlortetracycline on Methane Production from Cattle Waste. Applied and Environmental Microbiology. 41:1 pp29-34.

Warris, P.D. 1982. Loss of carcass weight, liver weight and liver glycogen, and the effects on muscle glycogen and ultimate pH in pigs fasted pre-slaughter. J.Sci. Food Agric. 33:840.

Wittmann, W., P. Ecolan, P. Levasseur, and X. Fernandez. 1994. Fasting-induced glycogen depletion in different fibre types of red and white pig muscles-relationship with ultimate pH. J. Sci. Food Agric. 66:257.

Young, B. A. 1986. Food intake of cattle in cold climate; symposium proceeding feed intake by beef cattle. OK State Ag. Exp. Station MP 121:328-340.

Zinn, R. A. and F.N. Owens. 1983. Influence of feed intake level on site of digestion in steers fed a high concentrate diet. J.Anim. Sci. 56:471-475.

Zinn, R. A. 1990. Influence of time of a day on live weight measurements for feedlot steers. J. Anim. Sci. 68(4):915-918.

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