EFFECT OF FEEDING HIGH LEVELS OF BROILER LITTER ON MINERAL METABOLISM AND HEALTH OF BEEF COWS

by

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(ABSTRACT)

Some cattle producers have reported metabolic disturbances in beef cows fed high levels of broiler litter. Therefore, an experiment was conducted to evaluate mineral metabolism of beef cows fed different levels of broiler litter. Sixty Angus-Hereford crossbred cows ranging in age from 3 to 12 yr were blocked by age, BW, and stage of gestation, and randomly allotted within blocks to three diets: 1) mixed hay, full fed; 2) 4.1 kg of a mixture of 80% broiler litter and 20% corn meal plus mixed hay (low-litter diet); and 3) 8.2 kg of the 80% litter and 20% corn meal mixture plus mixed hay (high-litter diet). Cows fed the litter diets were fed 57 g of magnesium oxide per head per day in the litter-corn mixture. Cows fed the three diets had access to a high-Mg mineral mixture. Experimental diets were fed from January 4, 1995 to April 19, 1995, and calving began on March 15. There were no physical signs of metabolic disturbances in any of the cattle. Blood serum Ca decreased and P levels increased in the cows fed both levels of broiler litter after the first 28 d on experiment. On d 28, average serum Ca values were 8.5 mg / dL for the cows fed hay, compared to 7.9 and 7.6 mg / dL for those fed the low and high levels of litter, respectively ($P < .01$). The average serum P values were

5.7, 8.2, and 9.1 mg / dL, respectively ($P < .01$). Generally, serum Ca remained lower and serum P remained higher for the cows fed broiler litter until the end of the winter feeding period (105 d). By mid-summer, serum Ca and P were similar ($P > .05$) for cows that had been fed the three diets. Serum Mg, Cu and Zn were not affected by feeding litter. Urinary Ca and Mg, expressed as units per unit of creatinine, did not differ ($P > .05$) among treatments. Serum parathyroid hormone (PTH) was higher ($P < .05$) in cows fed the lower level of litter than those fed the higher level in April (105 d). Serum PTH values for cows fed hay were intermediate. Birth weights, rate of gain, and weaning weights of calves did not differ among the three diets. Feeding high levels of broiler litter to beef cows appears to affect serum Ca and P.

Key Words: Broiler litter, Beef cows, Minerals, Animal health

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Chapter I

Introduction

The amount of broiler litter produced in the United States annually is approximately 4.7 million tons, DM basis (Fontenot, 1991). Traditionally, this litter has been applied as fertilizer to crop land. However, with the ever increasing amounts of waste produced in concentrated areas of poultry production, the disposal of this waste on limited land resources has led to public concern about environmental pollution. The run-off of phosphates and nitrates into water sources are the main concern. Environmental pollution is a concern that animal scientists need to, and are, addressing. Therefore, research has been conducted for several years to examine the safety and benefit of feeding broiler litter to livestock.

Feeding litter creates another avenue for waste utilization. The high fiber and non-protein nitrogen (NPN) of broiler litter makes it better suited as feed for ruminants than nonruminants. The cost of poultry litter is much lower than traditional feedstuffs. Usually the price of the litter amounts to 10 to 30% of its value. Utilization of poultry wastes in ruminant diets is a method to lower overall feed cost to the farmer. The Ca and P content in litter is relatively high, compared to traditional feedstuffs, possibly affecting the mineral homeostasis of animals consuming high levels in their diet. Poultry wastes have been used in practical feeding for different classes of beef cattle for over 30 yr with no major problems, and potential exists for increasing utilization of these by-products.

Feeding of litter to gestating beef cows allows for additional utilization of this waste, and a reduction in feed cost. However, reports from farmers and veterinarians have implied that the feeding of litter to cows has led to metabolic health problems, mainly parturient paresis. The cause(s) of these metabolic disturbances is not known. Different theories have been presented to explain the complex mineral interactions encountered by the feeding of high levels of broiler litter. Thus, the objective of this experiment was to determine the effect of feeding high levels of broiler litter on the mineral metabolism and health of mature gestating/lactating beef cows.

Chapter II

Review of Literature

Broiler litter is composed of excreta, bedding, feathers, and wasted feed, and can be processed and successfully fed to ruminants (Fontenot et al., 1966; Bhattacharya and Taylor, 1975).

Nutritional Value of Broiler Litter

The nutritional value of broiler litter depends largely on bird density, feed composition, feed spillage and length of time from excretion to collection (Forsht et al., 1974).

Crude Protein. Fontenot et al. (1971) reported that the average CP content of broiler litter obtained from various sources was approximately 30%, DM basis. True protein N comprised almost one-half of the CP in litter, uric acid N following with 30.5% and NH_3-N comprising 13.2% (Bhattacharya and Fontenot, 1965). Koenig et al. (1978) reported that rumen microbes were capable of utilizing uric acid N in poultry waste after a 2-to 3-d adaptation period. Therefore, ruminants can utilize much of the N in litter. Reports have indicated that uric acid in poultry waste is a superior N supplement to urea for beef cattle forage diets (Oltjen and Dinius, 1976), mainly due to the slower breakdown rate of uric acid in the rumen (Oltjen et al., 1968).

Apparent digestibility of N from poultry litter has varied from 65 to 82% (Ammerman et al., 1966; Bhattacharya and Fontenot, 1966). When comparing broiler litter processed by autoclave, dry heat, and acid plus dry heat to soybean meal, Harmon et al. (1974) found that the method of processing litter had no significant effect on N utilization in lambs. The results of an experiment by Caswell et al. (1975) agree with these results, where it was shown that processing methods, such as autoclaving, dry heat pasteurization, or dry heating with paraformaldehyde addition, had no significant effect on N utilization or apparent digestion coefficients in sheep. However, when comparing the apparent digestibility of CP in: 1) unsupplemented ensiled high-moisture corn; 2) ensiled corn supplemented with dry heat processed litter; 3) ensiled corn supplemented with soybean meal; or 4) ensiled corn-litter mixture fed to wethers, Caswell et al. (1977) found that apparent digestibility of CP was lower ($P < .01$) for both litter-containing diets than for the soybean meal diet.

Energy. The energy value of broiler litter can be a valuable asset to ruminant diets. When broiler litter was fed to sheep, the digestible energy value was found to be 2,440 kcal / kg (Bhattacharya and Fontenot, 1966). This value is comparable to a roughage such as alfalfa hay. In diets fed to sheep, containing either peanut hull or wood shaving litter, consisting of 50% broiler litter, the digestibility of energy was 72.7% (Bhattacharya and Fontenot, 1966). Generally, when the litter level increased in the sheep diet, the energy digestibility decreased. Ammerman et al. (1966) reported that apparent digestibility of organic matter in citrus pulp based broiler litter, calculated by difference, was 80.7%.

Bhattacharya and Fontenot (1966) found that as the level of broiler litter increased in sheep diets, crude fiber digestibility decreased. Broiler litter contains approximately 17% crude fiber (Fontenot and Ross, 1980). The high ash content in litter may be a limiting factor to the energy value.

Minerals. Broiler litter is relatively high in minerals in comparison to traditional feedstuffs. Ash content may vary widely. Samples of litter, taken from 13 broiler houses in Virginia and processed, had an ash content averaging 28.8% (Fontenot et al., 1971). The Ca, P, and Mg content averaged 2.3, 1.8 (Bhattacharya and Fontenot, 1966), and .44% (El-Sabban et al., 1969), respectively. Broiler litter is highly variable in Cu content, ranging from 98 to 593 ppm (El-Sabban et al.,1969; Westing et al., 1985). Trace minerals are found in higher concentrations in broiler litter than in conventional feedstuffs (Westing et al., 1985).

Absorption of Ca, P, and Mg by sheep, from a poultry litter supplemented diet, was examined by Ben-Ghedalia et al. (1982). Mean net absorption of Ca, P and Mg for the soybean meal (SBM) and poultry-litter (PL) treatments, respectively, was reported as 31.6, 10.1; 34.7, 35.4; and 51.5, 41.6%. Calcium absorption from the poultry litter-supplemented diet was lower than that from the soybean meal-supplemented diet. The overall net absorption (%) of P was similar for both diets. Net Mg absorption (%) was higher in the SBM diet than in the PL diet.

However, the daily amount of Mg absorbed from the PL diet was about twice that from the SBM diet. The results of this experiment supports the view that poultry litter is a good source of P and Mg for sheep. Bull and Reid (1971) found that Ca and P in dried caged layer waste were 95 and 72% available, respectively, as the only source of supplemental minerals in a ruminant diet. Cooke and Fontenot (1990) observed that broiler litter was a good source of available P and Mg for ruminants. In an experiment in which wethers were fed a low-P basal diet and supplemented with either broiler litter, swine waste, dicalcium phosphate, or soybean meal, apparent P absorption was not different ($P > .05$). However, when P absorption was calculated by difference, absorption tended to be higher from the waste supplements (59%) than from dicalcium phosphate and soybean meal (37%).

In a study in which deep-stacked broiler litter was fed to crossbred steers with initial weights of 204 kg, Rankins et al. (1993) concluded that dietary inclusion of broiler litter increased serum P and decreased serum Ca ($P < .07$). Other trials, that examined serum mineral values of cows fed differing levels of broiler litter, will be discussed later in the literature review under the topic of health and safety.

Performance of Ruminants Fed Broiler Litter

Feeding trials were conducted by Noland et al. (1955) with both gestating-lactating ewes and fattening steers in which ground chicken litter was used to replace conventional protein concentrates. Results showed that the ewes fed ground chicken litter performed as well as those fed SBM. When fattening steers were pair-fed diets supplemented with either ground chicken litter or cottonseed meal, at equal feed intakes, steers fed litter did not gain as rapidly. However, by increasing the total feed intake of the steers fed chicken litter by 15%, rate of gain was nearly equal to that of steers fed cottonseed meal.

Fontenot et al. (1966) found no difference in rate of gain in steers fed fattening diets containing 25% litter with different base materials of peanut hulls, corncobs, chopped-grass hay, and soybean hulls. However, rate of gain was higher for the steers fed the control diet, compared to the corresponding litter diets. Carcass grade and dressing percent were not markedly affected when either 25% or 40% litter was included in the diet (Fontenot et al., 1966). Cross et al. (1978) fed broiler litter silage (BLS), ensiled separately from other feed ingredients at 36% moisture, to beef steers for 200 d. The diets consisted of 30% concentrate plus (1) 70% corn silage (CS); (2) 60% CS and 10% BLS; (3) 40% CS and 30% BLS; (4) 20% CS and 50% BLS; (5) 70% BLS, DM basis. The diet containing 70% BLS was switched to 44% BLS and 56% corn after 35 d due to low consumption. Steers fed 10, 30, and 44% BLS gained at a faster rate than controls.

During a 90-d growth trial, steers fed 40% of their dietary N from two processed poultry waste products gained weight more ($P < .05$) rapidly and efficiently than steers fed similar dietary percentages of N from either urea or biuret (Oltjen and Dinius, 1976). When dried broiler excreta was used to provide either one-half or all of the supplemental N in a steer finishing diet, weight gains were not different (P > .05) from those obtained with a control diet (Cullison et al., 1976). Performance of ruminants fed different levels of animal waste was summarized by Smith and Wheeler (1979). Feeding diets containing an average of 24% poultry litter, DM basis, to cattle resulted in a 5% depression in rate of gain, probably reflecting the lower energy value of litter than the portion of the diet that was replaced. No differences were found in carcass quality and organoleptic characteristics of the meat from heifers fed broiler litter / corn forage silage or soybean meal as a supplemental N source (Westing et al., 1985).

Pregnant ewes fed a diet consisting of 63% broiler litter had similar single lamb birth weights, adjusted 90-d weight, and ADG as ewes fed a diet consisting of 87% alfalfa hay (Galmez et al., 1970). In a second trial, lambs were fed rice hull base broiler litter at 38, 48, 58, and 68% levels in the diet, which was fed *ad libitum*. Control animals were fed alfalfa hay. Daily gains were 84 g for the control lambs and 208, 186, 174, and 170 g for the lambs fed the four respective levels of litter. Growing sheep, that were fed diets containing 25 or 50% dehydrated poultry waste, gained significantly less than those fed a control corn-corn cob-soybean meal diet (Thomas et al., 1972).

Dairy cows fed a diet containing 11% dehydrated feces from caged layers, DM basis, produced more milk than those fed inadequate protein, and produced equal amounts to those fed traditional protein supplements (Thomas et al., 1972). Silva et al. (1975) fed dried poultry waste to lactating cows at 0, 10, 20, and 30% of the complete diet. Milk yield was reduced slightly (2.9%) for the 10% diet, but progressively lower yields (19.4 and 34.5%) were reported for the 20 and 30% diets. Milk production data from cows fed dehydrated poultry excreta (DPE) were summarized by Smith and Wheeler (1979). The mean daily milk production of cows fed diets containing DPE was only slightly lower (.25 kg) than production of cows fed traditional diets. Fontenot and Webb (1974) reported that gestating beef cows could be wintered on a mixture of 80% broiler litter and 20% ground corn plus a small amount of hay, 1 kg DM. A small amount of hay or other forage should be fed for normal digestion and health. The course fiber in hay promotes proper rumen function by providing tactile stimulation of the epithelium of the anterior rumen, thus inducing the animal to ruminate (McDonald et al., 1995). Rumination stimulates saliva excretion. Large amounts of saliva are needed in the rumen to prevent acidosis. Without hay inclusion in litter diets, animals often show signs of digestive disturbances.

Processing of Broiler Litter

Processing of broiler litter serves to destroy pathogens, improve keeping qualities, and improve palatability to the animal. Several methods have been developed to process broiler litter, including dehydration, ensiling alone or with other forages, deep stacking, and composting. The processing method depends on the purpose or use of the finished product, availability of other feedstuffs, and cost.

Dehydration. Dehydration, by mechanical means, is a process by which poultry litter is heat dried. The advantage of this process is the keeping quality of the litter. The disadvantages are the high cost of fossil fuels, the loss of N during processing, and the dusty nature of the product (Fontenot, 1991). Experiments were conducted by Harmon et al. (1974) to study the effect of acidifying broiler litter with sulfuric acid prior to processing on N loss during dry heat treatment. Starting with an initial pH of 7.7 for the unprocessed litter, approximately 30 mL of 1 N sulfuric acid were required to bring 100 g of litter to a pH of 6. Nitrogen loss averaged 13.9% for dry heat treated litter, but the loss was decreased to 7.5% by acidifying the litter prior to heat treatment. A study by Tagari et al. (1981), using heat-sterilized poultry litter in lamb diets, suggested that P absorption was lower in heat-sterilized litter than in air-dried poultry manure.

Ensiling. The ensiling process is characterized by the production of heat and organic acids. Broiler litter can be ensiled alone or with other ingredients. When litter is ensiled alone, water may be added to the litter to ensure the proper moisture for fermentation to occur, with maximum fermentation reported at 40% moisture (Caswell et al., 1978). Corn forage is perhaps the most often used forage to ensile with broiler litter. For good ensiling the level of litter should not exceed 40% (DM basis) of the silage (Harmon et al., 1975).

McClure and Fontenot (1985) found that finishing cattle had similar performance when fed corn-litter silage as heifers fed conventional corn silage with protein supplement. Chester-Jones and Fontenot (1981) conducted an experiment to compare performance of steers fed corn silage supplemented with deep stacked or ensiled broiler litter. Average daily gains were higher for cattle fed ensiled litter (1.16 kg) and soybean meal (1.15 kg) than those fed the deep stacked litter (1.02 kg).

Deep Stacking. Deep stacking involves the process of stacking litter to a minimum of 1.2 m in depth and leaving the stack to go through a natural heating action without any further mixing (Fontenot, 1991). During the deep stacking process it is recommended that the litter be stored in a well ventilated shed.

Dana et al. (1978) studied the changes in deep-stacked broiler litter with time. Wood shaving litter was stacked at a depth of 4.5 m in a covered building open on all sides. Temperature readings were taken at 45 and 80 cm from the surface of the stack daily. Temperatures at 45 cm were consistently higher than those at 80 cm with a maximum temperature of 54° C at 45 cm after 1 wk and 45.8° C at 80 cm after 3 wk. Microbiological assays were performed initially and throughout the 6-wk experiment. *Salmonella,* and *Shigella* were not present at any time. Total coliform assay revealed one colony at the dilution of 1:100. Fecal coliforms were not observed at any time during the course of the study. Hovatter et al. (1979) analyzed deep-stacked samples for pathogens. Microbiological assays on initial samples gave counts of 1 x 10^4 coliform colonies and 1 x 10^4 fecal coliforms per gram of litter. Tests for *Salmonella*, *Shigella* and *Proteus* were negative in all samples. After 1 wk of deep-stacking the litter tested negative for coliforms and fecal coliforms.

Dana et al. (1979) conducted a feeding trial with 30 straightbred and crossbred weanling beef heifers. Three diets were fed, containing a full feed of corn silage plus: 1) deep stacked broiler litter substituted for 30% of the corn silage DM; 2) ensiled broiler litter substituted for 30% of the corn silage DM; or 3) SBM plus defluorinated phosphate supplemented to the corn silage. Crude protein tended to be higher for the deep-stacked litter (35%) than the ensiled litter (31.4%). Average daily gain was highest (.89 kg) for heifers fed corn silage plus deep stacked litter, with heifers fed corn silage, plus ensiled litter or SBM, having lower (.8 kg) daily gains . Hovatter et al. (1979) fed weanling steers and heifers seven different diets, consisting of 0, 20, 40, 60% ensiled litter, or 20, 40, 60% deep-stacked litter, DM basis, of the diet. Rate of gain for cattle fed either 20% ensiled or deep stacked litter diets were highest (1.07 kg), with gain lowest (.52 kg) for cattle fed the 60% ensiled litter diet.

Rankins et al. (1993) studied apparent digestibilities of broiler litter, deep-stacked by three methods, when fed to steers. The litter was deep-stacked in three ways: (1) uncovered, (2) covered with .1524 mm clear polyethylene and (3) surfaced-watered to form a 2.5 cm crust upon drying. Two levels of litter were included in the diets, 25 and 50%, DM basis. Control animals received urea as a supplemental N source. Feeding litter depressed ($P < .04$) apparent dry matter, organic matter and gross energy digestibilities regardless of stacking method. Apparent digestion of N was decreased by feeding uncovered and watered litter only. Steers consuming the control diet gained weight faster than those consuming litter diets ($P < .01$). Litter processing method had no effect on ADG.

Composting. Composting involves initial stacking of the wastes, then mixing to enhance aerobic fermentation. This method of processing can result in considerable loss of N. Abdelmawla et al. (1988) composted litter by stacking, mixing after 2 d, then at weekly intervals for 6 wk. They found a 15% decrease in CP. Due to the loss of N and perhaps energy during composting, this type of litter is most often used for land application. Composted litter may be fed to animals but it is not as high in nutritive value as some of the other processed litter-products.

Abdelmawla et al. (1988) fed composted, deep-stacked and ensiled broiler litter to sheep at the level of 30% of a basal diet (DM basis). The ensiled litter-supplemented diet showed higher ($P < .01$) CP digestibility than deep stacked and composted litter-supplemented diets.

Safety Aspects of Feeding Poultry Wastes

Pathogens. Alexander et al. (1968) examined 44 field samples of poultry litter for the presence of different bacterial species. Poultry litter tested positive for numerous species of bacteria including, *Clostridium*, *Corynebacterium*, *salmonella*, *Staphylococci* and *Streptococci*. Animal wastes may contain potential pathogens, but to date, there have been no documented reports of any disease or illness caused by consumption of meat from animals fed wastes.

Processing of broiler litter by means of dehydration, ensiling, deep-stacking, or composting effectively kills most pathogens present in broiler litter (Fontenot et al., 1971; Messer et al., 1971; Caswell et al., 1975). Broiler litter was sterilized by heat drying for 3 h at 150^0 C (Fontenot et al., 1971).

Messer et al. (1971) reported that four potential pathogens were destroyed by heat processing of poultry litter. The four pathogens, *S. typhimurium, S. pullorum, Arizona sp.,* and *E. coli,* required heat of 47.2° C to 68.3° C for 30 to 60 min, depending on the pathogen.

The process of ensiling litter alone or with low protein feedstuffs, has proven to lower or eliminate coliform counts (Harmon et al., 1975). Broiler litter was ensiled at three levels (15, 30 and 45%) with corn forage. After fermentation, the pH of the silages ranged from 3.67 to 4.68 and lactic acid ranged from 4.19% to 8.82%, DM basis. The coliform population was significantly lower for silages containing litter than for the control silage. During the ensiling process, lactic acid-producing bacteria that occur naturally on plant material ferment water-soluble carbohydrates to lactic and acetic acids (McCaskey and Anthony, 1979). Growth of microorganisms, present in the feedstuff, is suppressed by this acid production and anaerobic condition of fermentation. Heat processing destroys potential pathogens (Fontenot and Webb, 1975). Ensiling broiler litter with 20 to 50% water destroyed coliforms (Caswell et al., 1978)

Botulism. Botulism is an acute toxicosis which usually results from the ingestion of pre-formed toxins of *Clostridium botulinum* (McIlroy and McCracken, 1987). Isolation of the *Clostridium* spores or toxins have been difficult. Many suspected cases of botulism have been reported in cattle (Appleyard and Mollison, 1985; Bienvenu and Morin, 1990; Hogg et al., 1990; Trueman et al., 1992). Many of these animals were grazing pastures which had been fertilized with poultry litter. In all cases, poultry carcasses were found in the litter that was either spread on the fields or mixed into the feed of the suspected affected animals. McLoughlin et al.(1988) reported a major outbreak of botulism in cattle being fed ensiled poultry litter. Eighty of a group of 150 housed beef cattle showed classical signs of botulism after eating a batch of ensiled poultry litter. Sixty-eight of the animals died and *Clostridium botulinum* type C toxin was detected in 18 of 22 sera examined. The poultry litter that was used in the feed mixture was purchased from a neighboring farm and observation was made of decomposed poultry carcasses in the purchased litter. Other confirmed cases of botulism have been made in cattle consuming poultry litter (McIlroy and McCracken, 1987; Neill et al., 1989), but in each case poultry carcasses were present in the litter.

Residues. Webb and Fontenot (1975) analyzed broiler litter samples from several Virginia broiler houses for medicinal drug and mineral levels. Samples were analyzed for oxytetracycline, chlortetracycline, penicillin, neomycin, zinc bacitracin, nicarbazin, amprolium, arsenic and copper. Detectable levels of all residues were found in the litter with the exception of neomycin and zinc bacitracin. *Longissimus* muscle, liver, and kidney fat samples were collected from cattle in two trials, in which litter was fed at 0, 25, or 50% of the diet. Chlortetracycline residues at low-levels were observed in kidney fat from 3 of 20 animals fed litter, while all other samples were negative. Of the tissue samples taken, there was a trend for As residues in muscle and liver to increase as the amount of litter fed increased. There was an accumulation of Cu in the liver as a result of feeding litter. In summary, Webb and Fontenot (1975) concluded that drug residues are frequently found in broiler litter but feeding litter to cattle resulted in little or no drug accumulation in tissues tested after a 5-d withdrawal of litter.

Health. Poultry litter has been safely included in ruminant diets for more than 30 yr. High levels of litter fed to sheep caused Cu toxicosis (Fontenot et al., 1972). Recent reports from veterinarians and farmers have indicated that feeding high levels of litter has been associated with hypocalcemia, Cu toxicosis, ammonia toxicosis, and enterotoxemia (Pugh et al., 1994b; 1994c). Ammonia toxicosis was reported by veterinarians responding to a survey conducted in Alabama (Pugh et al., 1994c). Definitive diagnosis of ammonia toxicosis is difficult, and only one case of broiler-litter-associated ammonia toxicosis has been confirmed by the State of Alabama Veterinary Diagnostics Laboratory. Enterotoxemia was also reported by the surveyed veterinarians. However, with proper processing such as either ensiling or deep stacking, pathogenic bacteria can be controlled.

Copper toxicity. Copper toxicity has been documented in sheep fed broiler litter with high Cu levels. Fontenot et al. (1972) reported that 64% of ewes fed 50% broiler litter for 254 days died of copper toxicity and 55% died that had consumed 25% litter in their diet. The litter contained an average of 195 ppm Cu and the diets containing 0, 25, and 50% litter analyzed 17.8, 57.1 and 109.1 ppm Cu. Olson et al. (1984) used mature nongestating, crossbred ewes to examine the influence of supplemented Mo and sulfate (SO_4) to high Cu broiler litter diets on tissue Cu levels. Liver Cu content increased ($P < .01$) by feeding broiler litter (404 vs 1,543 ppm, dry basis), and was decreased (962 ppm) by supplementing Mo and SO_4.

Beef cattle are more tolerant of high Cu levels in the diet than sheep. Webb and Fontenot (1975) conducted two feeding trials with beef cattle in which 0, 25, or 50% of the diet was composed of broiler litter. The diets were fed for 121 d for trial 1 and 198 d for trial 2. *Longissimus* muscle, liver and kidney fat samples were collected. Copper levels were considerably higher in the liver than in the longissimus tissue. In trial 1, liver Cu tended to be higher for the cattle fed litter than for the controls. In trial 2, liver Cu levels were significantly ($P < .05$) increased with increased litter intake. No Cu toxicity was reported in either trial, with beef cattle fed broiler litter containing an average of 259 ppm of Cu. Webb et al. (1980) evaluated the effect of long-term feeding of broiler litter on the performance of cows and upon the accumulation of Cu in the liver of cows. The first winter, 42 weanling heifers were randomly allotted to three diets. The heifers in lot 1 were fed 3.9 kg of mixed hay, 1.4 kg ear corn and .45 kg of a complex urea supplement per head per d. The animals in lots 2 and 3 were self-fed a mixture of 50% broiler litter and 50% ear corn. Copper was added to the diet in lot 3 to supply an additional 100 ppm Cu. For the next two years, the diets were as follows: lot 1 - mixed hay; lot 2 - 75% broiler litter, 25% ground ear corn; lot 3 - 75% broiler litter, 25% ground ear corn and 160 ppm supplemental Cu. The diets remained the same for the next three winters with the exception that 80% broiler litter and 20% ground shelled corn was substituted for the 75:25 ratio of litter-corn in diets for lots 2 and 3. Hay was fed to cows on the litter diets at a rate of .9 to 1.4 kg per head per day for the last 3 yr. Liver biopsies were taken in the spring and fall. Liver Cu levels were higher in the spring following the feeding of broiler litter during the winter period. The cows fed litter and corn plus additional Cu had the highest liver Cu levels (averaged 968 ppm), while the cows fed hay had the lowest liver Cu levels (averaged 69 ppm). By the end of the summer grazing period, the liver Cu levels declined markedly. No detrimental effects of feeding broiler litter or broiler litter plus additional Cu were observed.

Copper toxicosis has been reported in cattle fed broiler litter containing 300 to 400 ppm Cu for extended periods of time (Banton et al., 1987). Two cases of Cu toxicosis were diagnosed in a herd of 80 Holstein cows fed diets consisting of 13.6 kg/cow chicken litter, and 1.4 kg/cow of corn, minerals, soybean meal, and cottonseed, DM basis. Copper concentrations in the blood, liver and urine were all above normal range at 7.5, 436, and 1.3 ppm, respectively. Reports from a second herd of crossbred feedlot steers, indicated Cu toxicosis when 15 steers died after consuming a diet with a base of 9 kg broiler litter per steer, DM basis. The diets were fed for a 2-wk period before clinical signs appeared. Liver samples contained 730 ppm Cu.

Metabolic Disorders. Broiler litter is high in Ca and P (Bhattacharya and Fontenot, 1966). This high mineral content has resulted in a concern for metabolic disorders such as hypocalcemia. In a survey by Pugh et al. (1994c), 21 veterinarians out of 42 respondents indicated that they had treated hypocalcemia in herds where litter was fed. Ruffin et al. (1995) reported on documented cases of hypocalcemia. In a herd of 60 cows, that were fed 80% broiler litter and 20% corn screenings with free choice mineral mix, three cases of hypocalcemia were confirmed two seasons in a row. The breeds of cows affected were one Angus, two Angus-Charlois, one Angus-Simmental, and two Simmental. The animals ranged in age from 7 to 10 yr of age, 2 to 4.5 weeks postpartum and had been introduced to the litter diet within 1 to 2 wk before or after calving.

Rankins and Rude (1995) fed brood cows broiler litter for 4 to 5 mo pre-calving and showed that those cows had significantly lower serum Ca than cows not fed litter. In another experiment by Rude and Rankins (1995), it was noted that serum Ca was highest (8.9 mg / dL) for cows fed a control diet of Bermudagrass hay and lowest (7.5 mg / dL) for cows fed broiler litter with no supplemented hay. The cows fed broiler litter with 1.6 kg hay / day had intermediate serum Ca (8.4 mg / dL). Pugh et al. (1994a) conducted a study with 30 adult, pregnant, mixed breed beef cows. The control animals (G3) were fed coastal bermudagrass hay free choice pre-calving and coastal bermudagrass hay with a mixture of 1 kg ground corn and 0.5 kg cottonseed meal/cow/day post-calving. The litter diets were: (G1) - 2.5 to 3.5 kg coastal bermudagrass hay plus a mixture fed free choice of 80% broiler litter and 20% ground corn with 44 kg of $CuSO_4$ added per 1,000 kg of feed; (G2) - same as G1 without the added $CuSO_4$. Calcium sulfate was added as an intake limiter. Cows in G1 consumed approximately 6.8 $kg \cdot cow^{-1} \cdot day^{-1}$ of the broiler litter /corn diet, while the cows in G2 consumed approximately 9 $kg \cdot cow^{-1} \cdot day^{-1}$ of the litter/corn mixture. Serum Ca concentrations were lowest for G2 cows at parturition, while P concentrations were highest in this group at parturition. There were no significant differences in serum Ca and P between G1 cows and G3 cows. Serum Mg at parturition did not differ among groups.

Hypocalcemia

Milk fever, or clinical parturient paresis, is a recognized metabolic disease associated with hypocalcemia; low blood ionized calcium concentrations. The incidence of milk fever is highest immediately following calving and the first 2 wk post-partum (Block, 1984). Research has pointed to various methods for prevention of hypocalcemic parturient paresis. The regulation of Ca and P intake and Ca:P ratios in the prepartum diet of cows has been examined by many researchers (Beitz et al., 1974; Goings et al., 1974; Jorgensen, 1974). The theory of low Ca intake prepartum and ratios of Ca:P no less than 1:1 is considered a traditional prevention routine. Others (Gast et al., 1977, 1979) have examined the use of oral or parenteral administration of vitamin D or its metabolites at specific times prepartum. Although treatment with vitamin D and its metabolites is effective for preventing milk fever, timing of treatment in relation to actual calving date appears critical to efficacy of treatment (Block, 1984). Manipulation of the cation-anion balance of prepartum diets is being studied to determine the effect if any on cows consuming feeds that are high in Ca and P. Broiler litter is high in both Ca and P.

Cation-Anion Balance

The cation-anion balance (CAB) in animal diets can have major implications on productivity, longevity, and health of animals consuming a particular diet. The CAB is a ratio of cations to anions, usually expressed as units per 100 g of DM in a diet. The most commonly used equation is milliequivalents (mEq)(Na + K) - Cl / 100 g DM. Some researchers include S as an anion in the CAB equation because sulfates can directly alter acid-base balance if included at high dietary concentrations (Whiting and Draper, 1981). Unless the diet is high in protein, or sulfates are intentionally added to a particular diet, S does not need to be included in the equation.

The importance of Na, K, and Cl in the body in osmotic balance, acid-base balance and integrity and pumping mechanisms of cell membranes (Church and Pond, 1988), emphasized that these ions are most important in studying CAB. If in fact all feed ions were used, the balance would be maintained at zero due to the fact that plant material, once living, must be electrically neutral (Block, 1984). Many studies have been done manipulating the CAB of animal diets.

When using both synthetic and natural diets with poultry, experiments have shown that when the CAB is higher or lower than 25 mEq / 100 g (as fed) in the diets, growth is depressed (Mongin, 1981). This may be due to the fact that with increased or decreased CAB, an interference occurs in the metabolic pathways, causing the chick to expend more energy for homeostasis. Halloran (1980) showed that with the addition of $NaHCO_3$ to the diets of laying hens, egg shell quality could be increased.

With respect to prepartum and lactating animals, the CAB need is vastly different, mainly due to the vast difference in nutrient requirement from gestation to lactation (Block, 1984). When CAB in the diet of pregnant and lactating goats was either in excess (mean of 90 mEq / 100 g DM in the diet) or deficit (mean of .7 mEq / 100 g DM in the diet), plasma electrolyte concentrations were altered significantly (Freden et al., 1988). These changes caused metabolic acid-base imbalances and major differences in Ca and P metabolism. Significant amounts of data have been presented to show that cationic diets are desirable for lactation (Sanchez and Beede, 1994; Sanchez et al., 1994). Tucker et al. (1988) found that dietary CAB greater than 10 mEq / 100 g DM resulted in greater milk yield in dairy cows than lower CAB levels. The more controversial and less understood period for manipulating the ion balance in cattle diets is during gestation.

Traditional theories of low Ca diets or vitamin D therapy to prepartum cows for prevention of hypocalcemia (Payne, 1989) are being over-shadowed by new developments in altering the CAB in diets (Block, 1984). Block (1984) showed that feeding anionic diets to prepartum dairy diets is advantageous. In a 2-yr study with mature dairy cows, Block (1984) tested whether dietary anions and cations would influence the incidence of hypocalcemic parturient paresis (milk fever). Incidence of milk fever in cows fed the anionic diet was zero, whereas the incidence of milk fever in cows fed the cationic diet was 50%. Average intakes of Ca and P for the 2-yr trial were similar for both diets. Intakes were 85.5 and 33.9 g / d for cows offered the cation diet and 92.5 and 32.2 g / d for cows offered the anion diet.

CHAPTER I I I

EFFECT OF FEEDING HIGH LEVELS OF BROILER LITTER ON MINERAL METABOLISM AND HEALTH OF BEEF COWS.

ABSTRACT

Some cattle producers have reported metabolic disturbances in beef cows fed high levels of broiler litter. Therefore, an experiment was conducted to evaluate mineral metabolism of beef cows fed different levels of broiler litter. Sixty Angus-Hereford crossbred cows ranging in age from 3 to 12 yr were blocked by age, BW, and stage of gestation, and randomly allotted within blocks to three diets: 1) mixed hay, full fed; 2) 4.1 kg of a mixture of 80% broiler litter and 20% corn meal plus mixed hay (low-litter diet); and 3) 8.2 kg of the 80% litter and 20% corn meal mixture plus mixed hay (high-litter diet). Cows fed the litter diets were fed 57 g of magnesium oxide per head per day in the litter-corn mixture. Cows fed the three diets had access to a high-Mg mineral mixture. Experimental diets were fed from January 4, 1995 to April 19, 1995, and calving began on March 15. There were no physical signs of metabolic disturbances in any of the cattle. Blood serum Ca decreased and P levels increased in the cows fed both levels of broiler litter after the first 28 d on experiment. On d 28, average serum Ca values were 8.5 mg / dL for the cows fed hay, compared to 7.9 and 7.6 mg / dL for cows fed the low and high levels of litter, respectively ($P < .01$). The average serum P values were 5.7, 8.2, and 9.1 mg / dL, respectively ($P < .01$). Generally, serum Ca remained lower and serum P remained higher for the cows fed broiler litter until the end of the winter feeding period (105 d). By mid-summer, serum Ca and P were similar ($P > .05$) for cows that had been fed the three diets. Serum Mg, Cu and Zn were not affected by feeding litter. Urinary Ca and Mg, expressed as units per unit of creatinine, did not differ ($P > .05$) among treatments. Serum parathyroid hormone (PTH) was higher ($P < .05$) in cows fed the lower level of litter than those fed the higher level in April (105 d). Serum PTH values for cows fed hay were intermediate. Birth weights, rate of gain, and weaning weights of calves did not differ among the three diets. Feeding high levels of broiler litter to beef cows appears to affect serum Ca and P.

(Key Words: Broiler litter, Beef cows, Minerals, Animal health)

INTRODUCTION

Broiler litter is commonly fed to beef cattle throughout the world. Litter has been safely included in cattle diets for more than 30 yr, but recently there have been isolated reports in which feeding litter has been associated with metabolic problems in cattle consuming it, mainly hypocalcemia and hypomagnesemia. Broiler litter is high in mineral content including Mg and K (El-Sabbban et al., 1969). High dietary levels of K interfere with Mg absorption in ruminants (Newton et al., 1972) and can cause hypomagnesemic tetany in sheep (Suttle and Field, 1967). It is common practice to add MgO to diets containing poultry litter to prevent hypomagnesemia, more commonly known as grass tetany.

Hypocalcemia, or low blood ionized Ca concentration, occurs most commonly after parturition. Traditionally low Ca diets fed prepartum, have been the accepted prevention tool. It has been documented that high dietary Ca intake prepartum, increases the incidence of milk fever (Boda and Cole, 1956). Increases in dietary intake of Ca and P for gestating animals dramatically affects their metabolism and mineral balance (Block, 1984). The feeding of high levels of broiler litter has been suggested to cause hypocalcemia, because of the high dietary intake of Ca and P (Pugh et al., 1994a). Phosphorus, when fed at high levels can increase the incidence of milk fever (Julien, 1977).

The objective of this experiment was to assess the effects of feeding high levels of broiler litter on mineral metabolism, performance, and health of beef cows.

Materials and Methods

Sixty-three Angus-Hereford crossbred cows ranging in age from 3 to 12 yr were blocked by age, BW, and stage of gestation, and randomly allotted within blocks to three diets: 1) mixed hay, full fed; 2) 4.1 kg of a mixture of 80% broiler litter and 20% corn meal plus mixed hay (low-litter diet); and 3) 8.2 kg of the 80% litter and 20% corn meal mixture plus mixed hay (high-litter diet). Control animals receiving hay, were full fed from round bales, with fresh bales supplied as needed. For the litter-fed cows, the round bales were weighed and estimated quantities were unrolled daily to supply the desired levels of 4 $kg \cdot cow^{-1} \cdot d^{-1}$ for the low-litter diet and 1 $kg \cdot cow^{-1} \cdot d^{-1}$ for the high-litter diet. All hay bales were weighed with a pulley and hanging scale.

The broiler litter, corn meal, and MgO were weighed and mixed in a mixer wagon for 15 min for each of the two diets containing the litter-corn mixture. Each batch of feed was distributed evenly into three feed bunks, each approximately 4 m in length, per pasture. The cows were fed in pasture lots of approximately 3 ha, and rotated among pastures at each sampling date. The pastures were closely grazed before the trial began to limit grass availability. Cows fed the litter diets were fed 57 g of magnesium oxide (MgO) per head per day in the litter-corn mixture. Cows fed the three diets had access to a high-Mg mineral mixture. The custom mineral mixture (King Ag Products, Inc., Pulaski, Va), fed *ad libitum,* consisted of a minumum of 8.5% P, 11.2% Mg and 10.7 to 12.8% Ca.

The experiment was conducted at the Shenandoah Valley Agricultural Research and Extension Center, Steeles Tavern, Virginia from January 4, 1995 to April 19, 1995, and calving began on March 15. The litter diets were introduced gradually over a 2 wk period to acclimate the cows. The d 1 diet consisted of 2.27 kg/cow each of litter and corn, plus 57g of MgO. Each consecutive day the amounts of litter and corn were increased by .45 kg/cow, until the desired level of litter-corn mixture was achieved. At this time, the litter was increased by 5% each day and the corn was decreased each day by 5%, until the mixture was 80% litter and 20% corn meal.

Sample Collection and Analysis. One 14 mL blood sample was collected via jugular venipuncture from each cow on d 0, 28, 54, 84, 105 and post 78 for mineral analysis. A second 14 mL blood sample was collected on d 54, 84, and 105 for parathyroid hormone (PTH) analysis. Both sets of blood samples were collected and processed for serum (Vacutainer™, Becton Dickinson, Rutherford, NJ). Serum was separated by centrifuging the blood in a refrigerated centrifuge at 10 ^{0} C for 15 min at 1800 x *g*. Both serum samples were stored in polypropylene tubes at -20 ^{0} C until analyzed. Serum was analyzed for Ca, Mg, Cu, Zn, Na, and K *via* flame atomic absorption (Elmer-Perkin 5100 Z). Serum P was analyzed *via* colorimetric determination (Sigma Kit No. 360). Parathyroid hormone was analyzed *via* radio-isotropic assay (Kit from Nichols Institute, San Juan Capistrano, CA).

Urine samples were collected, by manual stimulation of the vulva, on days 54, 84, and 105 into polypropylene cups and kept on ice until processed. Urine was poured through 8 layers of cheesecloth into 14 mL polypropylene tubes and stored at -20^0 C until analyzed. Analysis for creatinine was performed with a quantitative, colorimetric determination at 500 nm (Sigma, No. 555). Urine Ca and Mg was read on the flame atomic absorption spectroscopy (Elmer-Perkin 5100Z). Urinary Ca and Mg concentrations were expressed as units of mineral per unit of creatinine, for a comparison of mean mineral excretion of cows fed different diets.

Hay samples were collected from each round bale *via* hand brace and bit and composited by weekly samples. Samples were stored in refrigeration until processed. Dry matter was determined on hay samples before they were ground for analysis. Corn and broiler litter samples were collected each day and composited into weekly samples and refrigerated similarly as the hay. Analysis of feeds followed standard A.O.A.C. (1990) methods of analysis for DM, CP and ash. Other components were analyzed by the methods as follows: neutral detergent fiber (NDF), Van Soest and Wine (1967) and Goering and Van Soest (1970); acid detergent fiber (ADF), Van Soest (1963) and Goering and Van Soest (1970); lignin and cellulose Van Soest and White (1968) and Goering and Van Soest (1970). Mineral determination, except for P, for the feeds were done *via* flame atomic absorption after wet ashing of the material (Sandel, 1959). Phosphorus analysis from feed samples were done using colorimetric determination (Fiske and Subbarow, 1925).

Cow body weights were taken at d 0, 28, 54, 84, 105, 183 and 288. Calf body weights were taken at birth, in March, April, July and September. Calves were weaned in September. The average age of the calves at weaning was 179 d.

Statistical Analysis. This experiment was a randomized block design. The data were analyzed within time of sampling using the general linear model for one-way analysis of variance procedure of SAS (1982). The degrees of freedom were 19, 2, 38, and 59 for block, diet, error, and total, respectively. The orthogonal contrasts were: 1) control hay diet vs. the litter diets, and 2) low litter diet vs. high litter diet. Treatment, block and treatment x block interactions were included in the model.

Results and Discussion

One cow in the low-litter fed group aborted a set of twin calves 19 d after the start of the trial. The entire block of cows were removed from any data analysis; thus, 60 animals will be referred to from this point forward.

Composition and Intake of Feeds

Dry matter content of the broiler litter, corn meal, and hay averaged 78, 89.3, and 71%, respectively (Table 1). The sample collection for hay was difficult in the winter months causing wet material to be included in the sample, thus the hay DM may not be a true representative value. The hay was dried in a forced air oven before any analysis was performed. The CP content of the three feeds were 29.13, 9.14, and 8.32% (DM basis), respectively (Table 1). These figures are similar to typical analyses reported from various sources (NRC, 1984). The CP of the hay was sufficient to meet the requirements of pregnant beef cows (NRC, 1984). The CP levels for the litter diets exceeded the requirements. Ash content was 21.5, 1.59, and 5.3% (DM basis) for the three feeds, respectively. The ash content of the broiler litter was similar to that reported by Fontenot (1991), and along with a high ADF concentration, is an indication of a low energy value for litter.

The Ca, P, and Mg content was 2.17, 1.75, and .72% (DM basis), respectively (Table 1.). With these levels of Ca, P, and Mg, the cows fed the highest level of

Table 1. Chemical composition of feeds[a]

Component	Hay	Corn grain	Broiler litter
Dry matter, %	71.3	89.3	78.0
Crude protein, %	8.32	9.14	29.1
Ash, %	5.30	1.59	21.5
Neutral detergent fiber, %	76.9	n/a	45.5
Acid detergent fiber, %	46.5	2.80	35.6
Lignin, %	9.35	.16	9.16
Cellulose, %	37.9	3.27	20.8
Calcium, %	.36	.02	2.17
Phosphorus, %	.18	.27	1.75
Magnesium, %	.25	.15	.72
Potassium, %	1.70	.42	1.83
Zinc, ppm	57	67	580
Copper, ppm	2.75	7.0	423

[a] DM basis except DM

litter, were consuming approximately two to four times their daily requirement (NRC, 1984). The Ca, P, and Mg values are similar to previously reported values in Virginia (Fontenot et al., 1966). Zinc and Cu concentrations were relatively high in the litter at 580 and 423 ppm, DM basis, respectively. Cows fed the low litter diet consumed approximately 3.28 $kg \cdot cow^{-1} \cdot d^{-1}$ of the broiler litter/corn meal mixture, while the cows fed the high litter diet consumed approximately 6.03 $kg \cdot cow^{-1} \cdot d^{-1}$ of the litter/corn mixture (Table 2.). Hay consumption was 5.54, 2.75, and 1.62 $kg \cdot cow^{-1} \cdot d^{-1}$ for the control, low-litter, and high-litter diet, respectively. The reported hay consumption for the control group is low due to apparent pasture consumption at the beginning of the trial.

Serum Mineral Values

No overt physical signs of hypocalcemia were observed in the cows on this trial. However, serum Ca and P concentrations were altered by the addition of broiler litter to the diets. No significant differences between the hay diet and the litter diets were detected for serum Ca, and P ($P > .05$) at the beginning of the trial (Tables 3 and 4, respectively). Serum Ca concentrations were lower ($P < .005$) on d 28 for both litter-fed groups (7.87 and 7.56 mg/dL, respectively), compared to the hay-fed group (8.5 mg/dL) (Appendix Figure 1). The high-litter fed cows had lower ($P < .05$) serum Ca concentration than the low-litter fed cows on d 28. Serum P was higher ($P < .01$) for both litter-fed groups (8.19 and 9.13

Table 2. Feed intake of cows fed different diets

	Diet[a]		
Feedstuff	Hay	Low litter	High litter
	----------kg^{-1}•cow^{-1}•d[b]----------		
Hay	5.56	2.75	1.63
Corn grain	0	.83	1.62
Broiler litter	0	2.45	4.68

[a] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.
[b] DM basis

Table 3. Serum calcium of cows fed different levels of broiler litter[a]

Day	Diets[b] Hay	Low litter	High litter	SEM
	---------- mg / dL ----------			
0	8.97	8.96	9.07	.085
28[cd]	8.50	7.87	7.56	.096
54[c]	8.20	7.79	7.75	.112
84[c]	7.77	7.58	7.44	.099
105[c]	7.67	7.20	6.88	.165
183[e]	8.01	8.17	8.08	.106

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Control vs litter diets differ ($P < .005$)

[d] Low vs high litter diets differ ($P < .05$)

[e] 78 d after end of feeding trial

Table 4. Serum phosphorus of cows fed different levels of broiler litter[a]

Day	Diets[b] Hay	Low litter	High litter	SEM
	---- mg / dL ----			
0	4.77	4.72	4.99	.140
28[cd]	5.72	8.19	9.13	.217
54[cd]	6.42	8.00	6.20	.270
84[cd]	5.53	6.43	7.11	.184
105[c]	4.27	6.95	7.04	.253
183[e]	3.99	4.12	3.90	.131

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Control vs litter diets differ (P < .01)

[d] Low vs high litter diets differ (P < .05)

[e] 78 d after end of feeding trial

mg/dL, respectively) on d 28, compared to the hay-fed group (5.72 mg/dL) (Appendix Figure 2). The high-litter fed cows had higher ($P < .05$) serum P concentration than the low-litter fed cows on d 28. Serum Ca concentrations remained lower ($P < .005$) and serum P concentrations remained higher ($P < .01$) for the litter fed cows on d 54, compared to the hay fed cows. However, on d 54, the high-litter fed cows had lower ($P < .05$) serum P concentrations than the low-litter fed cows. The explanation for the decline in serum P concentration for the high-litter fed cows on d 54 is not known. A hypothesis is that the cows were able to adjust to the diet, and better regulate serum mineral balance. On d 84, serum Ca concentrations were lower ($P < .05$) for lactating cows across all diets compared to gestating cows (Table 5). There was no treatment x stage of production (gestating vs lactating) interaction. Lower serum Ca levels are expected for animals in lactation due to increased Ca output in milk production. The trends of lower Ca and higher P concentrations for the litter-fed cows continued for d 84 and d 105. The data are consistent with other reported results. Rankins and Rude (1995) fed brood cows broiler litter for 4 to 5 mo pre-calving and showed that those cows had significantly lower serum Ca than cows not fed litter. Pugh et al. (1994a) reported that cows fed litter without an intake limiter, showed a decrease in serum Ca and an increase in serum P. Cows fed litter with the intake limiter, $CaSO_4$, consumed less broiler litter and showed no differences in serum Ca and P than cows fed hay. Gerken (personal communication) reported average serum Ca and P concentrations for a

Table 5. Serum calcium[a] of lactating vs gestating cows fed different levels of broiler litter[b]

Diets[c]	Parameter	Date March 30 (d 84)	SEM
		---------- mg / dL ---------------	
Hay	Gestating	7.90	.127
Hay	Lactating	7.62	.163
Low-litter	Gestating	7.71	.127
Low-litter	Lactating	7.32	.174
High-litter	Gestating	7.61	.123
High-litter	Lactating	7.17	.174

[a] Gestating vs lactating cows differ ($P < .05$)

[b] Least squares means

[c] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

Simmental crossbred cow herd fed broiler litter to be 7.80 and 8.46%, respectively. Cases of hypocalcemia had been diagnosed in this herd.

Homeostatic controls for blood Ca in mammals are efficient, maintaining Ca within very tight limits (Gerloff, 1988). When this intricate system of absorption and resorption fails, Ca concentrations fall below required limits in lactating animals, and signs of hypocalcemia occur. At parturition, milk fever may develop if plasma Ca drops below 5 mg/dL (Jacobson et al., 1975). The serum Ca concentrations did fall in the cows fed broiler litter, but not below the threshold that would cause hypocalcemia. Many other factors play a role in Ca homeostasis and these might account for the lack of clinically sick animals.

Consumption of high Ca prepartum diets has been associated with an increase in the incidence of milk fever (Julien et al., 1977). Cows with intakes greater than 100 g of Ca daily prepartum have a higher incidence of hypocalcemia (Julien, 1977; Gerloff, 1988; Oetzel, 1988). The percentage of Ca on a DM basis in the broiler litter/corn meal mixture was 1.74%, resulting in Ca intakes of approximately 57 g and 110 g, for the low-litter and high-litter diets, respectively. The Ca requirement for beef cows in late gestation is 25 g/d (NRC, 1984). The excessive Ca intake in the high-litter fed cows might account for the lower serum Ca concentrations in that group in contrast to both the hay-fed cows and the low-litter fed cows. The mechanism for maintaining serum Ca concentrations within acceptable limits is the rate of renal and intestinal absorption, along with bone resorption (McDowell, 1992). With excess Ca intake, the body increases renal excretion and decreases intestinal absorption and bone resorption.

Dietary intakes in the prepartum diet greater than 80 g of P daily, have also been associated with an increase incidence of hypocalcemia (Julien, 1977; Reinhardt, 1980; Oetzel, 1988). The percentage of P in the litter/corn mixture was 1.45%, resulting in P intakes of 48 g and 91 g for the low-litter fed cows and high-litter fed cows, respectively. The P requirement for beef cows during late gestation is 20 g/d (NRC, 1984). This would suggest that the high-litter fed cows had sufficient intake of P to increase their susceptibility to hypocalcemia and hyperphosphatemia.

Serum Mg (Table 6)(Appendix Figure 3) was not different among the cattle fed the different diets throughout the trial, except on d 28, when the litter fed cows had higher ($P < .05$) serum Mg in contrast to the hay-fed cows. The higher concentration of serum Mg in the litter-fed cows might be attributed to the added, MgO in the litter diets. The first 28 d on experiment might have served as an adjustment period for the cows consuming litter. Mean serum Mg concentrations for the different diets, ranged from 1.91 mg/dL to 2.46 mg/dL throughout the trial, which is considered within normal range (NRC, 1984). Studies by Pugh et al. (1994a) showed no difference in serum Mg values for cows fed litter compared to cows fed hay. Rude and Rankins (1995) had inconsistant serum Mg results, with higher serum Mg in litter-fed cows at calving and lower serum Mg in litter-fed

Table 6. Serum magnesium of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	---------- mg / dL ----------			
0	2.20	2.13	2.15	.070
28[c]	1.99	2.07	2.22	.055
54	2.23	2.26	2.38	.064
84	2.13	2.03	2.06	.082
105	1.91	1.97	2.08	.096
183[d]	2.43	2.44	2.46	.090

[a] Least squares means
[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.
[c] Control vs litter diets differ ($P < .005$)
[d] 78 d after end of feeding trial

cows 10 d post-calving. However, serum Mg values were within the normal range.

Hypomagnesemia of ruminants is a noninfectious metabolic disorder that occurs in a wide range of nutritional and management conditions (Smith and Edwards, 1988). The relationship of K, Ca, and Mg in the diet is an important factor in the development of hypomagnesemia. Diets high in K can cause hypomagnesemia even when Ca and Mg levels are within normal range. Two experiments were conducted to study the effects of a high dietary K intake on Mg metabolism in crossbred wether lambs by Newton et al. (1972). The diets fed to the lambs contained equal amounts of Mg, Ca, and Na and .6 or 4.9% K. Apparent absorption of Mg was greatly depressed ($P < .01$) while apparent absorption of Na and K was generally increased by the addition of 100 g of $KHCO_3$ to the diet. Increasing the level of dietary K of ruminants has been shown to depress the apparent availability of dietary Mg (Suttle and Field, 1967), and to reduce plasma Mg concentration (Suttle and Field, 1969). House and Van Campen (1971) fed wethers basal semipurified diets with or without daily supplements of 60 g KCl. Compared to animals fed the basal level of K, increased intake of KCl depressed ($P < .05$) Mg absorption. Greene et al. (1983), conducted a metabolism trial with crossbred wether lambs fed diets containing four levels of K (.6, 1.2, 2.4 and 4.8%). Grams of Mg absorbed decreased quadratically with dietary K level ($P < .05$). The largest depression in absorption (33%) occurred when the K level was increased from 1.2 to 2.4%. Broiler litter is high in K content, averaging 1.83% for this experiment. The addition of MgO to the litter fed diets probably prevented the incidence of hypomagnesemia.

Research has shown that hypocalcemia is often seen in conjunction with hypomagnesemia and hyperphosphatemia (Gerloff, 1988; Oetzel, 1988). The serum mineral concentrations of Ca (low of 6.88 mg/dL) and P (high of 9.13 mg/dL) in the cows fed the high-litter diet indicate a subclinical hypocalcemia and hyperphosphatemia state. However, if the cows were able to adjust to the diets before parturition, then clinical disorders could be avoided. Pugh et al. (1994) reported that cows fed litter on a 108-d trial, were able to regain normal Ca homeostatic control by 1 mo postpartum after being subclinically hypocalcemic at parturition. These cows were still consuming broiler litter diets.

Feeding the experimental diets ended in April due to pasture growth. Seventy-eight days after the cows were removed from the experimental diets, serum mineral concentrations were measured. At this sampling, serum Ca, P, and Mg were not different ($P > .05$, Appendix Figures 1, 2, and 3).

There were no significant differences in serum Na among cows fed the different diets (Table 7)(Appendix Figure 4) throughout the trial. Serum K concentration (Table 8) was higher ($P < .05$) in cows fed the high-litter diet than those cows fed the low-litter diet, at the beginning of the trial (Appendix Figure 5) and on d 54. The reason for this difference in serum K concentrations is not known. On d 105, the hay-fed cows had lower ($P < .05$) serum K concentrations than the litter-fed cows. Perhaps this was due to lower K in the hay diet.

Table 7. Serum sodium of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	---------- mg / dL ----------			
0	331.2	327.3	331.5	3.31
28	307.7	308.7	300.6	3.32
54	322.6	315.9	316.6	3.52
84	306.4	315.4	307.0	4.77
105	275.0	280.5	267.7	6.30
183[c]	268.5	272.3	269.4	2.75

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] 78 d after end of feeding trial

Table 8. Serum potassium of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	---------- mg / dL ----------			
0[c]	19.89	18.94	20.52	.478
28	16.84	17.47	17.77	.399
54[c]	18.90	17.87	19.28	.420
84	19.80	20.09	20.64	.444
105[d]	14.44	15.96	16.62	.485
183[e]	18.90	19.06	20.24	.752

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Low vs high litter diets differ ($P < .05$)

[d] Control vs litter diets differ ($P < .05$)

[b] 78 d after end of feeding trial

There were no significant differences among diets for serum Cu (Table 9) (Appendix Figure 6) throughout the trial. The mean serum Cu concentrations ranged from approximately 50 μg/dL to 70 μg/dL, and were within the normal range (NRC, 1984). The Cu concentration in the litter was high, but serum Cu concentrations were not affected by the litter diets. Hill and Matrone (1970) noted that Zn and Ag are antagonistic to Cu absorption. Since the litter was high in Zn, perhaps an interaction of Zn to Cu lowered the absorption of Cu. High levels of Ca in the diet will decrease the absorption of Cu and Zn (Maynard et al., 1969). The litter used in this experiment averaged 2.17% Ca. Cows fed the litter diets consumed 2-4 times their daily Ca requirement. This additional Ca intake could have affected the absorption of both Cu and Zn.

The concentrations of serum Zn (Table 10) were not different among diets throughout the trial, except on d 28 (Appendix Figure 7), the hay-fed cows had lower serum Zn values than the litter-fed cows. Although Zn concentration was relatively high in the broiler litter, the serum Zn concentration of the cows fed litter was within the normal range. Suttle and Field (1970) showed that high dietary Ca concentrations, reduced the absorption of tetracycline, Mn, and Zn. Since litter is high in Ca concentration, the absorption of Zn may have been decreased. Fontenot et al. (1964) fed Ca-to-P ratios of 1:1, 2:1, 4:1, and 8:1 to lambs with and without supplemental Zn (100 ppm). When no supplemental Zn was fed, rate of gain tended to be decreased at the higher Ca levels. Increasing the Ca level in the diet (above 1%) can have depressing effect upon the utilization of other

Table 9. Serum copper of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	---------------------------- μg / dL ---------------------------			
0	62.10	61.19	58.83	2.39
28	61.29	59.31	59.15	1.85
54	57.45	57.86	57.03	2.05
84	61.94	61.57	60.19	2.24
105	51.57	52.03	49.93	3.45
183[c]	69.20	67.43	66.49	2.10

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] 78 d after end of feeding trial

Table 10. Serum zinc of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	----- µg / dL -----			
0	82.62	83.57	80.07	2.66
28[c]	94.14	99.30	101.43	2.41
54	73.51	75.27	79.06	3.18
84	68.02	69.30	73.41	3.21
105	69.25	74.34	69.53	2.97
183[d]	93.95	98.70	91.77	2.65

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Control vs litter diets differ ($P < .05$)

[d] 78 d after end of feeding trial

nutrients and trace mineral elements in the diet, including Zn and Cu (Davis, 1959). The high Ca content of litter could negatively affect the absorption of Cu and Zn.

The variations among serum Mg, Na, K, Cu, and Zn were not consistent for any particular diet. The feeding of broiler litter has an effect on serum Ca and P. Without a complete understanding of the complex interactions between minerals, both macro and micro, few conclusions can be drawn about the effect of feeding broiler litter on total body mineral metabolism.

Serum Parathyroid Hormone

Parathyroid hormone plays an important role in Ca homeostasis, helping to regulate intestinal absorption and kidney resorption (Reinhardt et al., 1988). Serum PTH was measured on a subset of 21 animals (7 complete blocks) for d 54, 84 and 105 (Table 11). The PTH in serum that was collected on d 54, was at a period when none of the cows had calved, and values were similar for the diets. By the d 84 collection, approximately one-third of the cows had calved. Although there were no significant differences, mainly due to a very large variation in the readings, there was a trend for the high-litter fed cows to have a lower serum PTH concentration. In a study in dairy cows, Shappell et al. (1986) concluded that serum PTH concentrations were higher in heifers and cows fed a low Ca diet. Conversely, PTH concentrations were lower in the cows fed a high Ca diet, thus agreeing with this wintering cow experiment. Also, Shappell et al. (1986) reported

Table 11. Serum parathyroid hormone of cows fed different levels of broiler litter[a]

	Diets[b]			
Day	Hay	Low litter	High litter	SEM
	---------- pg / dL ----------			
54	253.8	308.4	327.1	71.62
84	309.8	285.2	194.1	69.83
105[c]	127.0	369.9	299.6	60.13

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Control vs litter diets differ ($P < .05$)

that the cows that received high Ca diets prepartum maintained elevated PTH for 3 d after parturition, most likely in response to the corresponding period of hypocalcemia. They showed data with dairy cows that would seem to agree with the data from cows fed both levels of broiler litter on this experiment obtained on d 105. The only significant difference among the diets was on d 105 when the hay-fed cows had lower ($P < .05$) serum PTH concentration (127 pg/dL) than the litter-fed cows (369.9 and 299.6 pg/dL, respectively)(Appendix Figure 8). By d 105, three-fourths of the cows had calved, and cows fed litter had higher ($P < .05$) serum PTH concentrations. With increased PTH concentrations, the litter-fed cows may have displayed a subclinical hypocalcemia, with PTH increasing in the blood to counteract the lower Ca concentrations. The complexity of Ca homeostasis and the interactions of mineral and hormonal factors are still not completely understood.

Urinary Mineral Values

Due to the variation in volume of urine excreted daily, a measurement of creatinine was used to equate the mineral concentration to a ratio for comparison among animals. Creatinine is the anhydride of creatine and is a constant constituent of normal human urine (Oser, 1965). It is assumed that creatinine is excreted at a constant rate, thus, creatinine can be used as an indication of urine excretion of minerals. The reported range of creatinine concentration in cattle urine is from 14 to 651 mg creatinine N $liter^{-1}$ (Bristow et al., 1992). Although this range of creatinine concentration in cattle is broad, Oser (1965) reported from human information that the level of creatinine excretion is practically constant for a given individual and is independent of changes in the total amount of N eliminated. Undoubtedly, the variation in volume of urine excreted daily is also great. Therefore creatinine was used in this experiment as a means for comparing urinary mineral excretion.

Urinary Ca concentrations per unit of creatinine (Table 12) varied widely and there were no significant differences among diets (Appendix Figure 9). Urinary Mg concentrations per unit of creatinine (Table 13) were not significantly different among diets. However, there was a trend for an increase of Mg excretion in the cows fed broiler litter (Appendix Figure 10). This may be partly explained by the additional MgO fed in the litter/corn mixture.

Body Weight Changes of Cows

The average BW at the beginning of the experiment for all cows was 543 kg (Table 14)(Appendix Figure 11). By d 54, BW of the high-litter fed cows averaged 583 kg, which was higher ($P < .05$) than for the low-litter fed cows. The high-litter fed cows continued to have heavier BW than both the low-litter fed cows and the hay fed cows. With the use of round bales as the source of hay, the regulation of

amount fed was difficult. For this reason, the cows in the high-litter group were

Table 12. Urinary Ca per unit of creatinine of cows fed different levels of broiler litter[ab]

	Diets[c]			
Day	Hay	Low litter	High litter	SEM
	---------------------- mg Ca / mg creatinine ----------------			
54	2.296	0.972	1.419	.653
84	0.774	0.874	1.104	.186
105	1.364	1.549	1.131	.342

[a] Least squares means

[b] Differences among diets not significant (P > .05)

[c] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

Table 13. Urinary Mg per unit of creatinine of cows fed different levels of broiler litter[ab]

	Diets[c]			
Day	Hay	Low litter	High litter	SEM
	------ mg Mg / mg creatinine ------			
54	8.77	11.20	11.12	1.72
84	5.51	7.52	8.02	1.18
105	5.47	5.61	5.81	1.69

[a] Least squares means

[b] Differences among diets not significant (P > .05)

[c] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

Table 14. Body weights of cows fed different levels of broiler litter[a]

Day	Diets[b]			
	Hay	Low litter	High litter	SEM
	---------- kg ----------			
0	545	534	551	7.07
28	574	564	580	8.35
54[c]	563	548	583	8.10
84[c]	535	536	577	9.75
105[cd]	487	497	544	9.47
183[ce]	544	536	565	9.86
288[f]	540	538	558	7.86

[a] Least squares means

[b] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[c] Low vs high litter diets differ ($P < .05$)

[d] Control vs litter diets differ ($P < .05$)

[e] 78 d after end of feeding trial

[f] Weaning date of calves from cows, September 27, 1995

fed more hay than would have been desired. Near the end of the experiment, small square bales were used to alleviate this problem.

Performance of Calves

The performance of calves gives an indication of cow productivity. There were no significant differences among diets for calf birth weight or weaning weight (Table 15). The average day of age for calves at weaning was 179 d. The weaning weights (adjusted 205 d) of calves were 243, 241, and 240 kg for the hay, low-litter, and high-litter fed cows. From these calf data, we can conclude that the cows fed broiler litter showed no decrease in production.

Table 15. Performance of calves[ab]

Time of weight	Diets[c]		
	Hay	Low litter	High litter
	----------	kg	----------
Birth	38.6	39.1	41.4
April 19	63.0	59.0	61.0
July 6	124	125	125
September 27[d]	214	217	215
Adj. 205 d	243	241	240

[a] Least squares means

[b] Differences among diets not significant ($P > .05$)

[c] Hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

[d] Weaning date of calves

Conclusions

The results of this experiment concur with the findings of Pugh et al. (1994a), Ruffin (1994), and Rankins and Rude (1995) that feeding high levels of broiler litter to gestating cows affects serum Ca and serum P concentrations. Although there were no physical signs of metabolic disorders, serum values for Ca and P were indicative of hypocalcemia and hyperphosphatemia. Serum Mg concentrations were within the acceptable range for cows. Other mineral values were not affected consistently by the litter-fed diets. Another indication of mineral homeostais is PTH concentration in the blood. Serum PTH varied widely among the experimental animals. On d 105, serum PTH was higher for cows fed litter diets. The findings of increased PTH concentration agrees with findings by Shappell et al. (1986) in which cows fed high Ca prepartum diets showed elevated PTH concentrations for 3-d after parturition. The increase in serum PTH in this experiment could be in response to the decrease in serum Ca concentration for the litter-fed cows. Urinary Ca and Mg values did not differ among diets. Cow body weights were higher in the high litter-fed cows throughout the experiment mainly due to the higher consumption of hay than desired. Calf performance did not differ for the groups of cows fed the different diets. High levels of broiler litter can be fed to gestating cows. Further experiments should be conducted to examine the effects of feeding high levels of broiler litter to continental breeds of cows that produce more milk per day.

CHAPTER IV.

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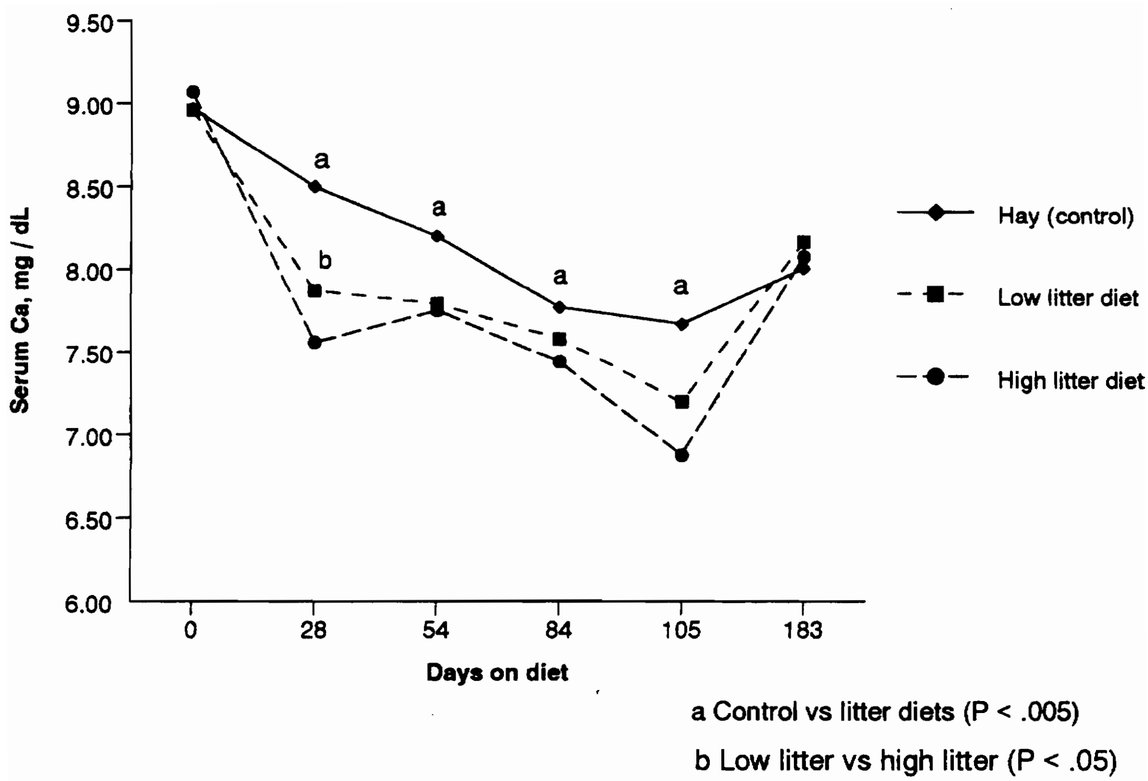
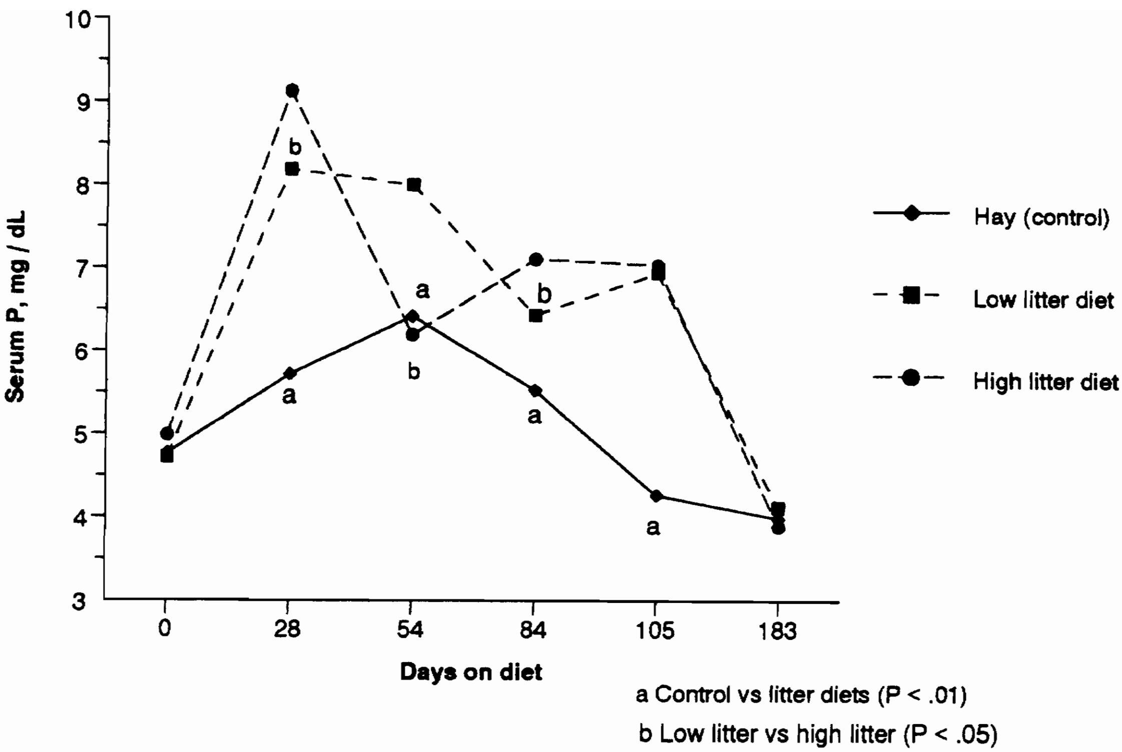
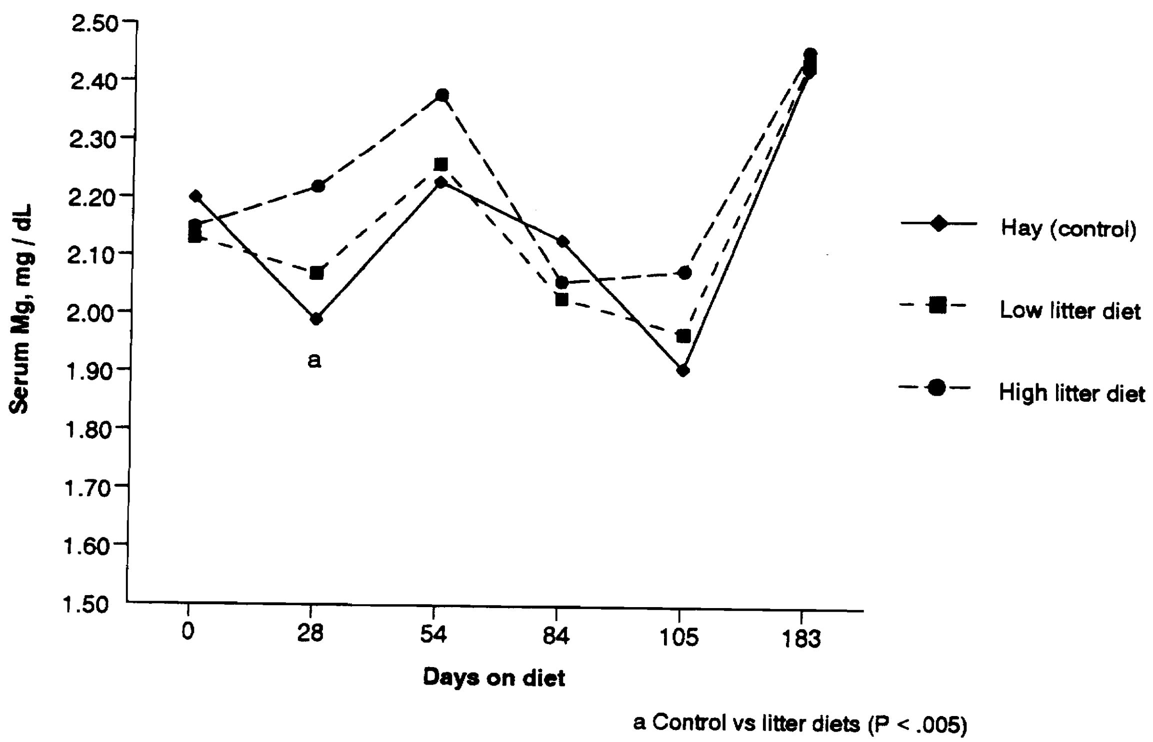
APPENDIX



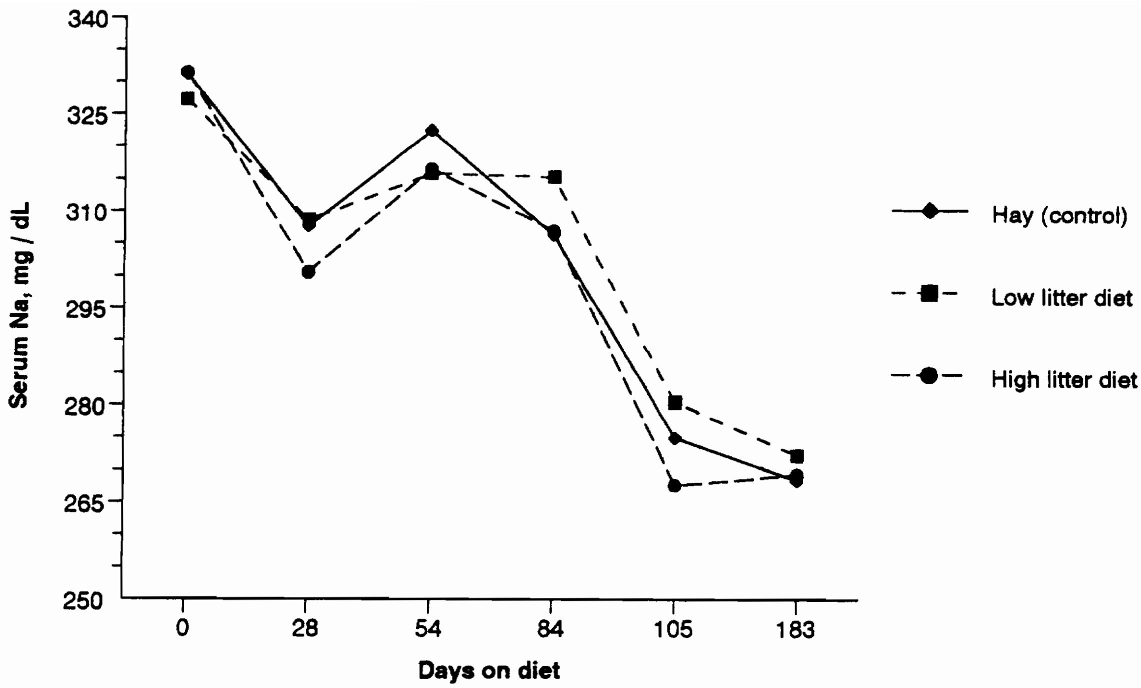
Appendix Figure 1. Serum calcium of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



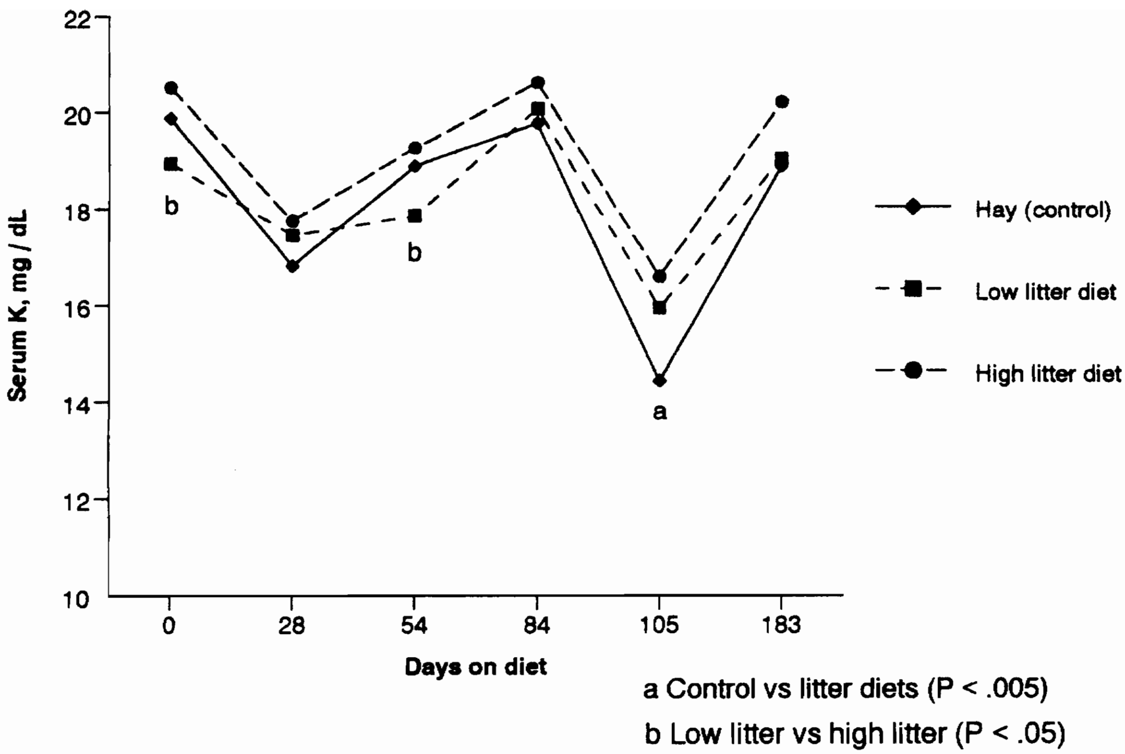
Appendix Figure 2. Serum phosphorus of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



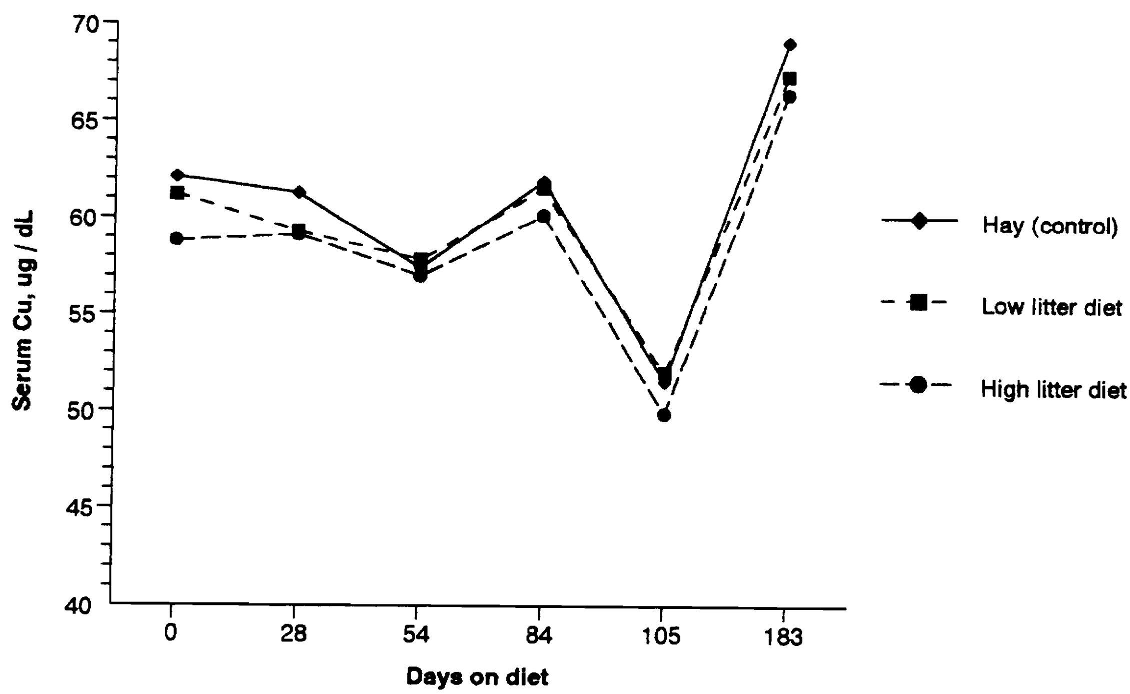
Appendix Figure 3. Serum magnesium of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



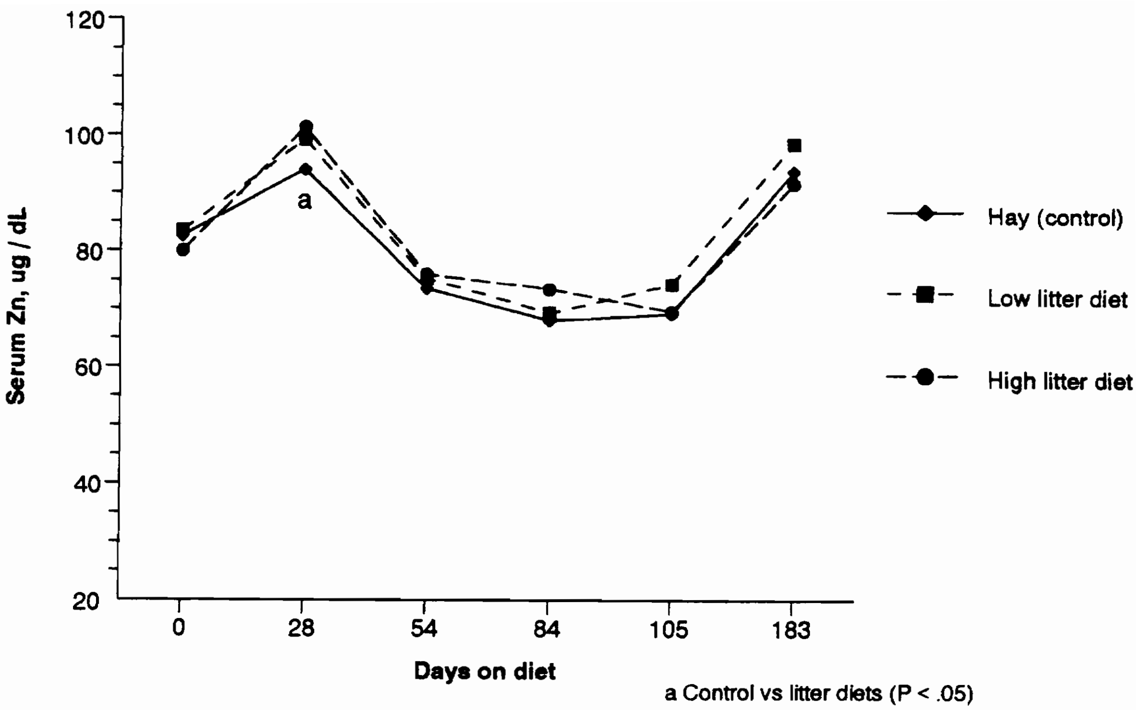
Appendix Figure 4. Serum sodium of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



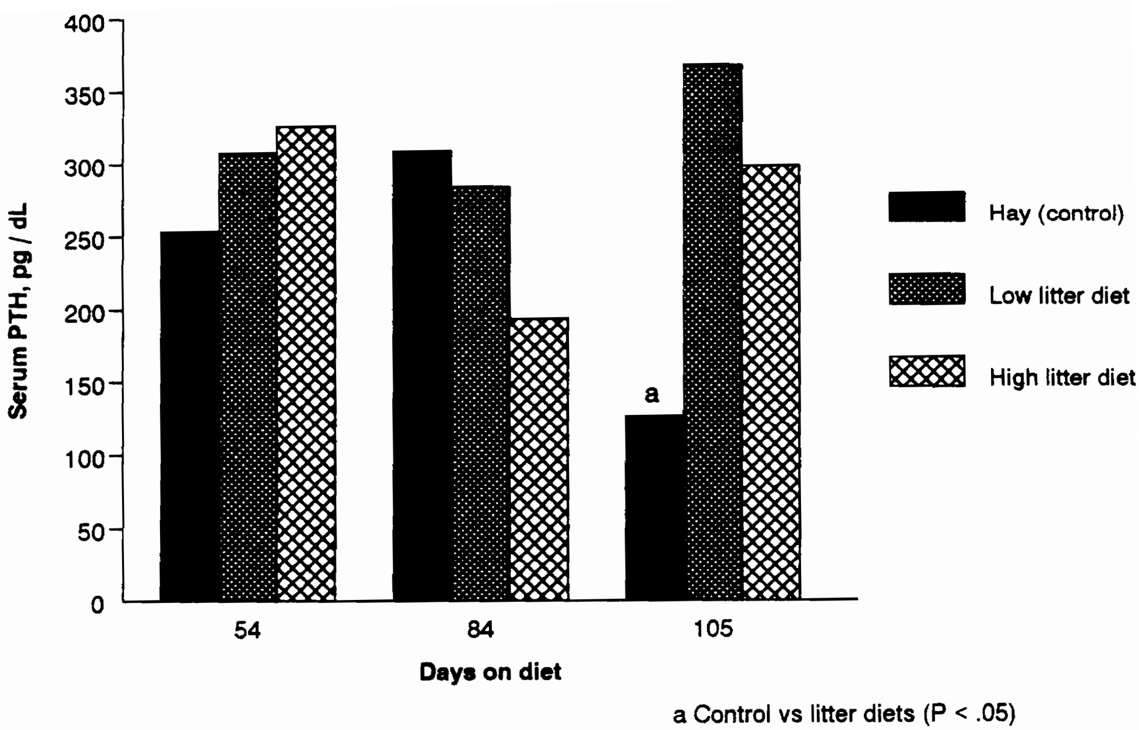
Appendix Figure 5. Serum potassium of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



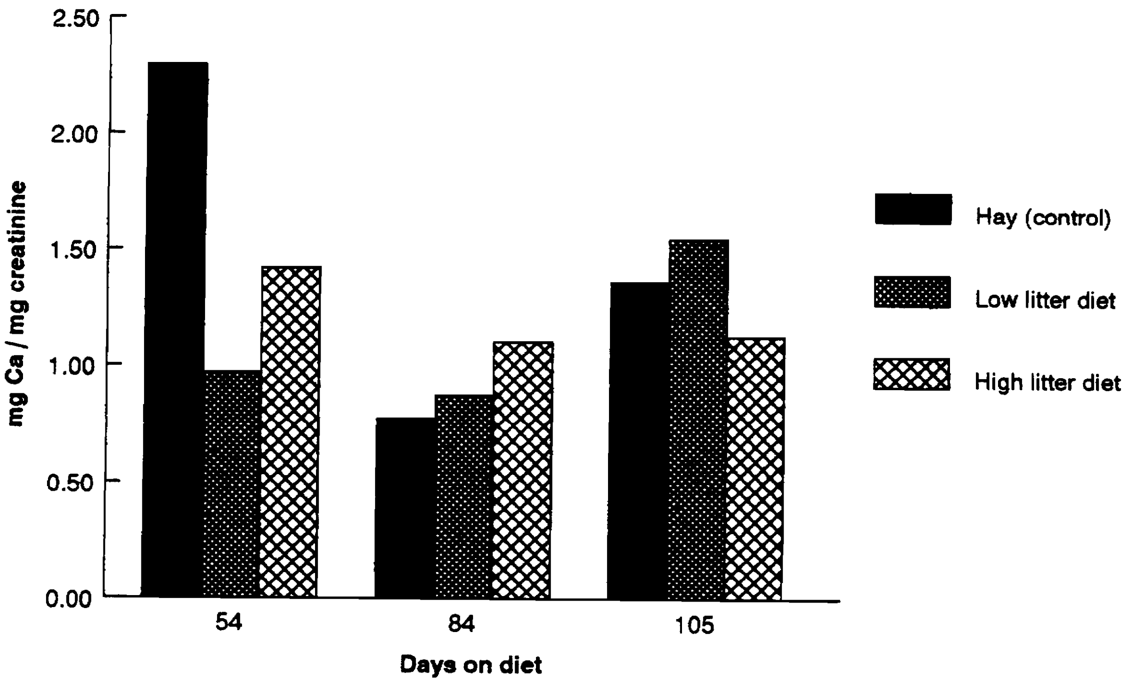
Appendix Figure 6. Serum copper of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



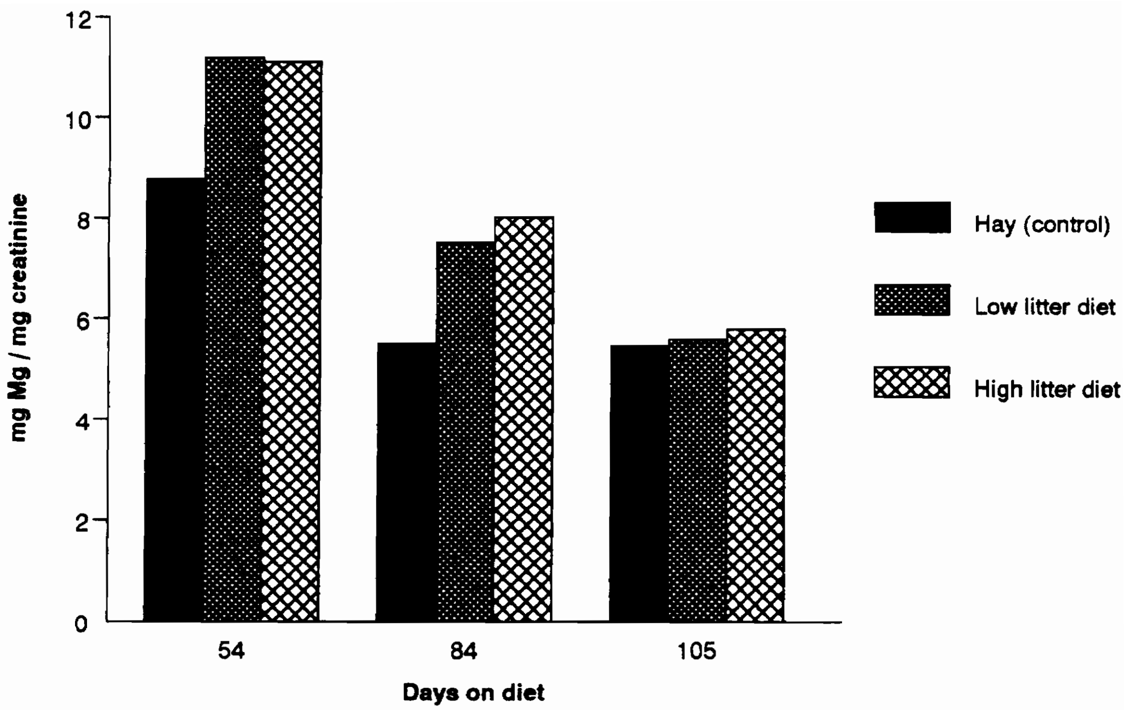
Appendix Figure 7. Serum zinc of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



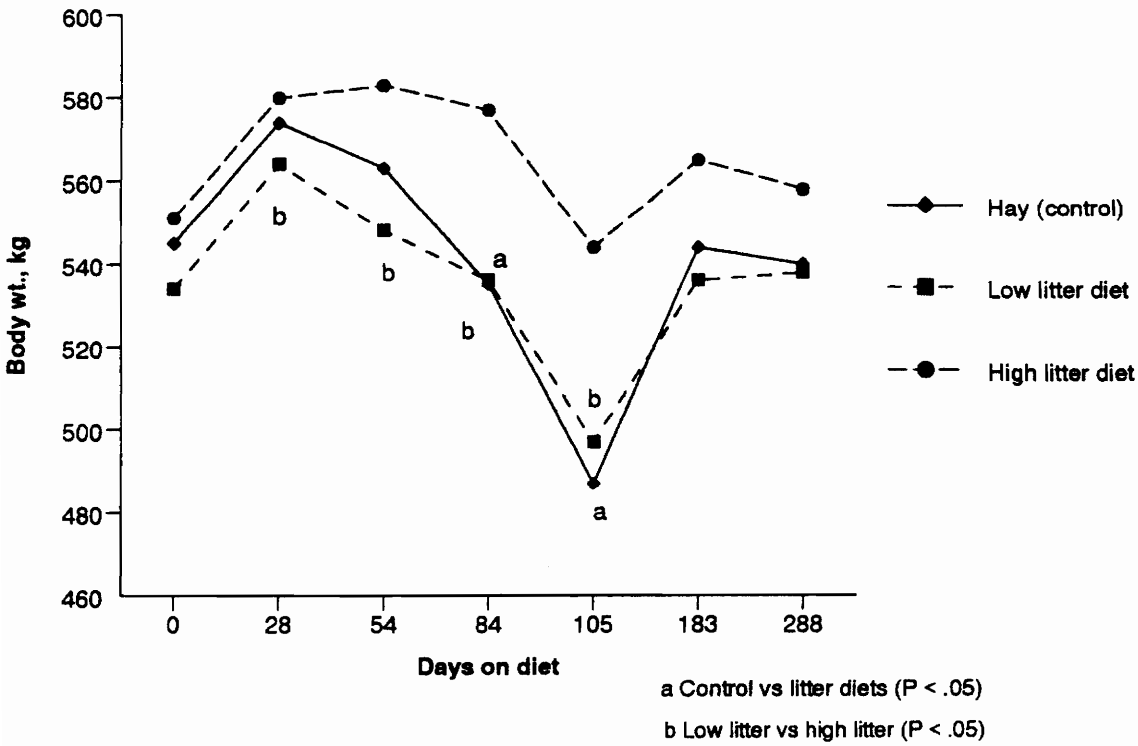
Appendix Figure 8. Serum parathyroid hormone of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



Appendix Figure 9. Urinary calcium per unit of creatinine of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



Appendix Figure 10. Urinary magnesium per unit of creatinine of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.



Appendix Figure 11. Body weights of cows fed different levels of broiler litter. Diets: hay, mixed grass, predominately fescue; low-litter, 41% litter; high-litter, 59% litter.

Vita

Martha Ann Wright was born September 4, 1966 in Utica, New York to Bruce and Joan Wright. She graduated from Greenwich Central High School in May of 1984. She received an Associate of Applied Science degree in Animal Husbandry at State University of New York, Cobleskill in May, 1986.

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