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Effects of Graded Levels of Dietary Lasalocid on Performance of Holstein Cows During Early Lactation

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EFFECTS OF GRADED LEVELS OF DIETARY LASALOCID ON PERFORMANCE OF HOLSTEIN COWS DURING EARLY LACTATION

by

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ABSTRACT

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Thirty-six multiparous Holstein cows were assigned to one of three dietary levels of lasalocid: 0, 180, or 360 mg/hd/d in a completely randomized design. Cows were assigned to treatments 1 wk postcalving and remained on treatment until 11 wk postcalving. Basal diets were composed of ground corn, alfalfa hay, alfalfa haylage, corn silage, and soybean meal, fortified with vitamins and minerals as needed. All ingredients were ground and fed as a total mixed ration. Daily rations were fed in two equal portions at 0500 and 1700 h at a rate to allow a 5-10% refusal. Daily measurements included milk production and dry matter intake (DMI). Milk composition (fat, protein, and somatic cells) was analyzed twice per week on Tuesdays and Fridays. Cow body weight (BW) and visual body condition were measured weekly. Production during previous lactation was used as a covariate in analyzing the data. Although milk production was not affected by dietary treatment, lasalocid tended to increase daily milk production by approximately 2.5

kg/d (P = .13) at both the 180 and 360 mg/hd/d levels. Percent milk fat and protein were not affected by dietary lasalocid (P = .84 and .78, respectively). Somatic cell count of the milk was not affected by dietary lasalocid (P = .17). Dietary lasalocid reduced DMI by approximately 1.5 kg/d at both the 180 and 360 mg/hd/d levels (P = .02). At the 180 and 360 mg/hd/d levels, lasalocid increased amount of milk produced per kg of DM consumed by .16 kg (P = .08). Neither BW (P = .89) nor body condition (P = .90) were affected by dietary lasalocid at either level. No effect of treatments was observed on blood metabolites. Glucose, nonesterified fatty acids, β-hydroxybutyrate, and cholesterol all fell within the normal ranges of blood serum.

(53 pages)

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INTRODUCTION

A long-cherished dream of ruminant nutritionists has been to manipulate and improve the efficiency of ruminal fermentation. In particular, this has meant being able to increase ruminal propionic acid yield, depress methanogenesis, and depress rapid ruminal proteolysis and deamination of dietary proteins. Such shifts in rumen fermentation should enhance the overall productive efficiency of ruminants. Initial attempts to achieve this goal were by dietary manipulation. But during the last several decades a number of active feed-grade compounds have been discovered that can achieve some or all of the above objectives and hence improve efficiency of production with growing ruminants. One such class of compounds is carboxylic polyether ionophore antibiotics (henceforth referred to as ionophores), which were originally used as anticoccidial feed additives for poultry. These ionophores are produced by various strains of *Streptomyces* and include monensin, lasalocid, salinomycin, and narasin, among others (9).

Genetic capability to produce large volumes of milk has increased greatly in Holstein cattle in the past few decades. Coincidental with this capability has come a requirement for more nutrient dense diets. During early lactation, nutrient intake seldom matches nutrient demand for milk production. Any feeding practice that would improve the overall health and productivity of the cattle would be beneficial to the industry.

Ionophores such as lasalocid have proven valuable in improving the efficiency of nutrient utilization in growing and finishing diets in beef cattle by increasing the production of ruminal propionate and decreasing the ruminal microbial degradation of dietary proteins. It stands to reason that these advantages could also be extrapolated to

lactating dairy cows. A major problem during early lactation is ketosis, which results from low blood glucose levels as mammary demands for lactose production increase. The two main gluconeogenic nutrients in cattle are propionate and amino acids. Since lasalocid should increase the supply of both of these nutrients, productivity and health should be improved. The objective of this study was to measure the effects of graded levels of dietary lasalocid on the productivity of Holstein cows during the crucial, early-lactation period.

LITERATURE REVIEW

Historical Background

The polyether antibiotics were first isolated 44 years ago (10). In 1951, in the course of searching for new antibiotics, three *Streptomyces* were isolated from soil samples from Montclair, New Jersey, Salem, Virginia, and Hyde Park, Massachusetts. These unidentified organisms were referred to as X-206, X-464 (nigericin) (91), and X-537A (lasalocid), respectively. When grown on a variety of media in aerated submerged culture, all three produced antimicrobially active substances. Three antibiotics were obtained in crystalline form, one from each of the organisms. Although the new antibiotics were chemically different, their biological activities and certain chemical properties were so similar that they are being reported here as a group. All three are colorless, optically active, organic acids containing C, H, and O. Their most likely empirical formulas are $C_{46\text{-}47}\,H_{80\text{-}82}\,O_{13}$ (X-206), $C_{25}\,H_{40}\,O_7$ (X-464), $C_{34}\,H_{52}\,O_8$ (X-537A). All three antibiotics are active in vitro against certain gram-positive bacteria and mycobacteria, but they are inactive against gram-negative bacteria and fungi (10). Sixteen years elapsed before the first structure was solved (1). Monensin was the first polyether antibiotic whose structure was elucidated. This report aroused considerable interest in the polyethers and approximately 30 had been reported by mid-1976. The structures of most of these polyethers were elucidated by X-ray analysis of heavy-atom salts or derivatives, but in the case of the monensin and lasalocid homologs, mass spectrometry was the technique that distinguished these closely related compounds (19, 91). The structure of lasalocid (X-

537A) was reported (55, 91) and shown to be the first polyether antibiotic possessing an aromatic chromophore (Figure 1). It is important to recognize that more than 75 ionophores have been identified to date.

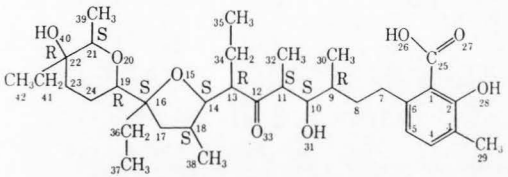

Figure 1. Chemical structure of lasalocid.

Early use of ionophores was primarily in the poultry industry for control of coccidiosis and improved feed efficiency. It was not until later that people began to understand the full potential and uses of ionophores in the cattle industry. Since their approval in feedlot diets in December of 1975, ionophores have gained wide acceptance by the cattle-feeding industry (41).

General Mechanism of Action for Ionophores.

Hoffmann-La Roche (51) stated that Pressman and coworkers were the first to classify polyether antibiotics as ionophores because of the ability of these antibiotics to induce cation permeability in biological membranes by carrying ions across lipid bilayers as lipid-soluble complexes. Thus, it is largely the ability of ionophores to transport cations into cells and either protons or other cations out of cells that is associated with their mechansim of action in biological systems (78). Hoffmann-La Roche (51) reported that

according to their ability to transport various cations, Pressman and Greenwald separated ionophores into three groups. These were (a) ionophores with a higher affinity for K+ than Na+ (e.g., lasalocid and nigericin), which produces an initial H+ in/K+ out-exchange followed by reequilibration of pH through a Na+ in/H+ out exchange; (b) ionophores with equal affinity for Na+ and K+ (e.g., lysocellin), which produces a Na+ in /K+ out-exchange with no change in pH; and (c) ionophores with a higher affinity for Na+ than K+ (e.g., monensin), which produces an initial Na+ in/H+ out-exchange followed by reequilibration of pH through a Na+ in/K+ out-exchange. Chen and Wolin (20) clearly demonstrated that ionophores selectively inhibit gram-positive organisms (those without an outer membrane) in preference to gram-negative organisms that have an outer membrane. Due to its structure, lasalocid is capable of binding a wide range of cations, including mono- and divalent cations and biogenic amines. The substances with which lasalocid is capable of complexing are shown below (in decreasing order of selectivity):

$$Ba2+ >> Cs+ > Rb+, K+ > Na+, Ca2+, Mg2+ > Li+$$

Ruminal bacterial population shifts associated with ionophore administration have resulted in molar changes in short-chain, fatty acid ratios, resulting in greater proportions of propionic acid and less acetate and butyrate. From a practical viewpoint, this shift in ruminal fermentation results in a significant decrease in methane production, which can result in upward of 10% conservation of feed energy.

A recent study (25) has shown that the antimicrobial effects of ionophores against some gram-positive bacteria can be reversed in the presence of excessive potassium. This data suggest that the antimicrobial and growth-promoting activities of lasalocid may be

significantly influenced by cation concentrations in the rumen. Dawson et al. (25) suggested that the antimicrobial activity of lasalocid may be influenced by sodium and potassium concentrations in the rumen. The supplementation of appropriate concentrations of these ions may significantly enhance the growth-promoting activity of lasalocid. A study conducted in 1983 (31) with graded levels of potassium to feedlot steers indicated that during the early part of the trial, potassium supplementation tended to increase rate of gain. But over the total trial, potassium supplementation at moderate levels (.70 to .85%) tended to reduce feed intake and significantly decreased energy intake and rate of gain. Feed efficiency was unchanged by potassium level. No effects of potassium on ruminal acid levels or ammonia concentration were apparent. But with higher potassium levels, rumination was less frequent. Regardless of the exact nature of the event, interference with normal ion flux must play a dominant role in the mode of action of ionophores within the rumen (54, 77).

Modes of Action

Since the early 1970's, ionophore research has centered mainly on the mode of action on ruminal microbial metabolism. Initial findings (28, 75) proposed that the mode of action of ionophores was the ability to decrease the molar proportion of acetic acid to propionic acid in ruminal fluid. Ionophores are now known to be involved in other metabolic processes in ruminants. Schelling (82) reported that ionophores affected 20 metabolic processes in ruminants (Table 1). Ruminal microbial growth, microbial metabolism, nutrient digestibility, and utilization are the main areas of ionophore activity

in ruminants.

TABLE 1. Metabolic processes affected by ionophores.

Increased ruminal propionate	Decreased ruminal acetate
Decreased intake of high energy diets	Increased intake of high roughage diets
Protein-sparing effect	Decreased gas production
Decreased methane production	Decreased proteolysis
Decreased deamination	Increase in rumen fill
Decreased rate of passage	Modified fiber digestibility
Decreased ruminal starch digestibility	Modified site of protein digestibility
Decreased ruminal lactate production	Increase in rumen pH
Change in microbial population	Increase in body pool of glucose
Decrease in use of plasma amino acids as gluconeogenic precursors	Earlier puberty in heifers of equal weights

Prevention of Environmental Diseases

Coccidiosis is a serious disease in cattle, sheep, goats, pigs, poultry, and rabbits. The intestine as well as the liver can be affected. Clinical coccidiosis is most prevalent under conditions of poor nutrition, poor sanitation, and overcrowding, or after the stresses of weaning, shipping, sudden changes of feed, or severe weather (88).

As was stated earlier, ionophores were originally used as an anticoccidial feed additive for poultry (9). Natural immunity to coccidiosis develops from prior exposure. It has been found that even small numbers of oocysts may induce good protection against coccidiosis. Since virtually all animals are exposed to coccidiosis at some time, coccidiosis is a disease of young, susceptible animals. Although cattle coccidia are related (all are in the genus *Eimeria*), part of the immunity is specific to each coccidia species.

There are two common pathogenic bovine coccidia, *E. bovis* and *E. zuernii*, and at least a dozen less-prominent species. In 1979, Foreyt et al. (33) found that both lasalocid

and monensin were highly effective (> 99%) in eliminating oocysts of five species of ovine coccidia used in the inoculum. Treated lambs gained an average of 6 kg more weight ($P < 0.05$) per animal than the untreated control lambs and consumed ($P < 0.05$) less feed for each kilogram gained.

Studies on the stage of action of ionophorous antibiotics against *Eimeria* were conducted by Long and Jeffers (58). Sporozoites of *Eimeria tenella* were treated with different anticoccidial drugs in vitro and their subsequent viability was tested by inoculating them into chicken embryos. Monensin, salinomycin, lasalocid, and arprinocid greatly reduced sporozoite viability based on mortality, hemorrhage, and specific lesions in the embryo chorioallantois. By initiating treatment of chickens with monensin at different times in relation to the infection, it was shown that the drug exerts its anticoccidial effect on the primary invasive stage and on the gametogenous stage of *E. tenella* and *E. necatrix*. Long and Jeffers (58) further stated that the effect on gametogony was tested by initiating infections in the second generation merozoites of *E. tenella*. Significant reduction in oocyst production occurred in three of the four strains of *E. tenella* tested. Medication with monensin initiated before merozoite inoculation was effective in inhibiting oocyst production, but medication starting 5 h after merozoite inoculation was not. The results showed that the ionophorous anticoccidial drugs exert their anticoccidial action primarily against the invasive stages of *Eimeria* spp. Other research studies (23, 50) indicated that lasalocid and decoquinate were efficacious coccidiostats and protected calves as long as they were administered. Cessation of drug treatment usually resulted in appearance of oocysts in feces and diarrhea. Also, preimmunization alone cannot be

expected to prevent coccidiosis when animals are exposed to large numbers of oocysts.

There is considerable information about sensitivity of coccidia to lasalocid and other ionophores in chickens. Braunius (13) reported the effectiveness of ionophores against *Eimeria* spp. coccidiosis in chickens. Hoffmann-La Roche (51) reported there is no doubt that the average field strain of chicken coccidia today is not as sensitive to ionophores as strains isolated during the pre-ionophore era. Occasionally, field strains are isolated that are nearly totally refractory to ionophores. However, there has not been widespread development of lasalocid-resistant broiler *Eimeria* spp. strains, and Avatec™ (lasalocid, 80g/lb) is a very useful anticoccidial drug for the broiler industry today.

Prevention of Metabolic Diseases

Lactic Acidosis. Huntington (52) defined acidosis as a condition of pathologically high acidity of the blood. In ruminants the term is expanded to include acidic conditions in the rumen (rumen acidosis). The condition can be acute, posing a life-threatening situation, or chronic (subacute), resulting in reduced feed intake, weight gain, or milk production. Statistics are not available on incidence of acidosis, but lambs appear to be more susceptible than cattle to acute, fatal acidosis as evidenced by increased death loss in cases of grain overload. In general, death losses due to acidosis in any group of ruminants are probably small and sporadic. Huntington further stated that the major physiologic and economic costs of lactic acidosis result from chronic acidosis that goes undetected in large groups of cattle or sheep where low feed intake and weight gain of the affected animals are masked until the group is slaughtered. Only after slaughter do economic analyses and

abscessed livers reveal the deleterious effects of lactic acidosis. Lactic acidosis is a major problem in high-producing dairy cows because the diets consist mainly of concentrates rather than roughages. The etiology of lactic acidosis has two major phases: (a) abrupt increase in ingestion of readily fermentable carbohydrates followed by rapid ruminal fermentation to organic acids, which lowers ruminal pH and alters the ruminal microbial population's profile, and (b) absorption of the acids into the bloodstream, resulting in acidosis. Acids produced in the rumen are absorbed into the bloodstream, where they accumulate and develop systemic acidosis. Blood pH is lowered and an electrolyte imbalance occurs due both to loss to the lumen of the gut and to high acid concentrations. High osmolarity of chyme and diarrhea cause loss of water from blood, and splenic release of erythrocytes in response to general physiological stress causes hemoconcentration. In severe cases, acidosis interferes with renal function and oxygen transport. Peripheral arterioles rupture, particularly in the extremities, and this is manifested as laminitis or founder (52).

Hoffmann-La Roche (51) indicated that ionophores that inhibit or depress the growth of gram-positive organisms would appear to be useful in controlling some of the problems associated with the production of high lactate levels and the problem of lactic acidosis in feedlot cattle fed high concentrate diets. Most ruminal bacteria that produce lactate are gram-positive. Several investigators (20, 26) have reported that polyether ionophores inhibited the growth of the major ruminal lactate-producing organisms.

Nagaraja et al. (67) conducted a study with lasalocid, monensin, and thiopeptin administered through intraruminal doses. Doses were 0, .33, .65, and 1.3 mg/kg body

weight (BW). They evaluated its effectiveness in preventing experimentally induced lactic acidosis in cattle. Four rumen-fistulated cattle were used for each dosage level of lasalocid, monensin, thiopeptin, or no antibiotic. Acidosis was induced by intraruminal administration of glucose (12.5 g/kg BW). Control cattle exhibited the typical drop in rumen pH and concurrent increases in L(+) and D(-) lactate concentrations commonly observed in cases of lactic acidosis. Alkali reserves were depleted in the control cattle as evidenced by a decrease in blood bicarbonate and a negative shift in base excess. Nagaraja et al. (67) showed that cattle given lasalocid had higher rumen pH and lower lactate concentrations than did cattle on control treatment or cattle given monensin or thiopeptin. Cattle given monensin had a significantly higher rumen pH and lower lactate concentration than controls, only at the 0.65 and 1.3 mg/kg BW dosages, whereas thiopeptin was effective only at the 1.3 mg dosage. Concentrations of total volatile fatty acids (VFA) in rumen fluid decreased in the controls, but remained unchanged in cattle given ionophores. A significant reduction in the molar proportion of acetate and an increase in the molar proportion of propionate was observed in the rumen fluid of the cattle given ionophores. Colony counts of *Streptoccus bovis* and *Lactobacillus* spp. were significantly reduced in rumen fluid of cattle given 1.3 mg ionophore/kg BW. Counts of lactate-utilizing bacteria increased in both control cattle and cattle given ionophores. Cattle given ionophores showed no evidence of lactic acidemia, hemoconcentrations, or change in acid-base balance (67). Other similar studies (65, 66) showed that ionophore-treated cattle had higher rumen pH values and lower lactate concentrations than control cattle that received no ionophores.

Bloat. Acute tympanites (bloat) is a noninfectious disease that is common among ruminants in many parts of the world. Bloat in sheep and cattle is not a new disease, but it has increased markedly due to improved forage systems such as legume utilization and intensive pasture fertilization. Essig (29) stated that the production of gas (primarily CO_2) in the rumen is a normal result of the fermentation process. There are several types of bloat that may or may not be associated with each other. The following are often discussed: (a) legume, (b) feedlot, (c) toxic [HCN and NH_3], (d) pathological (abscess), and (e) obstructive (adhesions).

Bloat can be categorized as being caused by free gas or frothy (legume) conditions in the rumen. Free gas bloat is usually present in feedlot animals under the influence of toxic, pathological, or obstructive conditions. Free gas in the rumen may also result from a failure of the mechanism for expulsion of fermentation gases. Essig (29) also reported that feedlot bloat may be a result of excessive consumption of rapidly fermented, dense feed that depresses the cardia below the fluid level, thereby causing a gas buildup in the rumen. This phenomenon of overfilling has been demonstrated by filling the reticulo-rumen with liquid and elevating the hindquarters of the animal, which resulted in inhibition of eructation with a gas buildup in the rumen.

Frothy bloat occurs in animals grazing lush legume pastures. Legumes are high in rhamnose content that, when consumed in large quantities, causes a viscous, slimy mass that traps fermentation gases and prevents eructation even though the intraruminal pressure may be above normal. There is a question whether frothy bloat is caused by an increased rate of gas production or simply by an entrapment and accumulation of gas in

the ingesta resulting in a failure of gas elimination. Majak et al. (60) indicated that chlorophyll concentration, buoyancy of particulate matter, and rates of gas production were significantly higher in bloated than nonbloated cattle allowed to graze alfalfa. It was suggested that the microbial colonization and retention on particulate matter provided active inocula for promoting rapid legume digestion, with enhanced gas production and entrapment. This produces a frothy mass resulting in bloat. In the grazing animal, the incidence and severity of bloat appears to depend on a complex interaction of the grazing animal, grazed plant, and rumen microorganisms. Essig (29) stated that it is commonly recognized that plants with a high protein content such as the temperate legumes, white clover, red clover, persian clover, and alfalfa (*Trifolium repens, T. protense, T. resupinatum L. and Medicago sativa*) are more bloat provocative than nonlegumes. Analyses of alfalfa bloat foams indicated that the foaming constituents are primarily proteinaceous. Soluble protein from legumes, a foam stabilizing protein, has physical and chemical properties that make it an ideal bloat-promoting agent. Soluble protein content of legume leaves may be a good indicator of a plant's bloat-provoking potential. By feeding ionophores to grazing livestock on legume pastures, protein degradation and incidence of bloat will be reduced. The interrelationship of plant, animal, and microorganism is necessary for bloat to occur, and the disruption of the influence of any of these factors will prevent or decrease the occurrence of bloat (29).

Methods of bloat prevention are many and varied. Antifoaming agents such as tallow and paraffin have been applied to the flank of the cow and subsequently licked off during the day. Antibloat agents such as emulsified oil and pluronic-type materials have been

added to water sources to prevent bloat. Antifoaming agents such as tallow and paraffin have been sprayed on pastures for bloat control. The use of these compounds is potentially reliable; however, failure to follow specific management recommendations along with unfavorable climatic conditions may lead to poor control of bloat. The best treatment of bloat is prevention (29). In spite of extensive research, bloat continues to be a common disorder in ruminant animals. Many studies suggest that diets as well as microbial factors play a major role in the development of bloat. Evidence that ionophores can be a major factor in reduction of bloat still has not been clearly established. Windels et al. (93) reported both lasalocid and monensin were beneficial in reducing bloat of steers fed a barley-alfalfa haylage diet. However, neither ionophore eliminated bloat entirely.

Sakauchi and Hoshino (80) suggested that monensin lowered the incidence of bloat due to a marked depression of rumen fluid viscosity. However, Bartley et al. (6) suggested that doses of .66 to .99 mg monensin/kg BW reduced legume bloat in cattle about 66% compared to pretreatment bloat scores. Similar doses of lasalocid reduced legume bloat about 26%. A dose of 44 mg poloxalene/kg BW (recommended dose for field use) reduced legume bloat 100%. Monensin or lasalocid combined with 25 or 50% of the recommended dose of poloxalene reduced bloat under that of the ionophore alone, but did not achieve 100% reduction. Bartley et al. (6) concluded that lasalocid and monensin, when given as a dose of 1.32 mg/kg BW, reduced bloat by 92 and 64%, respectively, in cattle bloated on high-grain diets. Lasalocid at .66 mg/kg effectively prevented bloat from developing when given to animals before the feeding of high-grain diets. However, a 1.32 mg/kg dose was required to control bloat in cattle that were

already bloating before they were given lasalocid (6).

Ketosis. Ketosis as defined by Schultz (84) is a metabolic disorder in which the level of ketone bodies in body fluid is elevated. These ketone bodies are β-hydroxybutyric acid, acetoacetic acid, and acetone. Ketosis of varying degrees can occur in all animal species by many different causes. In farm animals it is a practical problem primarily in the lactating dairy cow, ewes in late pregnancy, and the goat in either late pregnancy or early lactation. Thus, it is restricted to the ruminant species and associated with the energy drain imposed by advanced pregnancy (usually multiple births in sheep and goats) or high milk production in early lactation or both. Ketosis that occurs in the diabetic human is similar in certain respects, but the cause is the inability to utilize glucose due to a lack of insulin, rather than a glucose drain for productive purposes. The incidence is higher in older dairy cows, and certain cows tend to repeat, but the problem also occurs at first calving. Primary ketosis in dairy cows almost always occurs during the first 8 wk after calving, when there is peak lactation drain and energy intake has not synchronized or matched with output. About 3 wk after calving is the most critical period in dairy cows (84).

Many treatments have been suggested for ketosis, but only a few are still being used. The following are the most commonly used and most effective (35): intravenous glucose, hormones, and oral glucose precursors.

The vitamin (84) that has received the most attention in relation to ketosis is niacin. For some time rumen synthesis of B-vitamins has been considered adequate to meet the needs of ruminant species. Recent work (36) has raised the question of whether this is

adequate for high-producing cows in early lactation. Fronk and Schultz (36) reported beneficial effects of 12 g of nicotinic acid daily for cows with subclinical ketosis. Bartlett et al. (4) showed reduced urine ketones and a lowering of the incidence of clinical ketosis from 4.8 to 1.5% in a field study of nine herds with 508 cows when 6 g of niacin was fed daily for the first 10 wk of lactation. Although more definitive evidence is needed, existing evidence suggests that herds with a high incidence of ketosis may benefit from niacin supplementation in early lactation. Other reports showed that ionophores may possibly suppress ketosis in cows during early lactation. Sauer et al. (81) showed that feeding monensin at either 15 and 30 g/ton of feed during the postpartum period decreased the incidence of subclinical ketosis from 6 out of 12 to 1 out of 12 cows.

The concentration of serum β-hydroxybutyrate from cows receiving the high monensin level was decreased during the 3 wk postpartum experimental period. Ruminal acetate:propionate ratios decreased from 2.32 in the control group to 1.44 in the high monensin group. Feed intake in the low monensin group (13.9 kg DM) was less than in the control group (14.5 kg DM), but there were no significant differences in BW change or milk production. Monensin lowered milk fat in one monensin fed group (15g/ton), but not the other. Milk protein and lactose concentration were not changed by the addition of monensin to the diet. No other adverse treatment effects were observed.

Lasalocid Toxicity in Various Animal Species

Trials have been conducted with lasalocid in various species to determine the margin of safety should various species of animals accidentally be fed lasalocid at rates greater

than those appearing on the product label. The trials have been conducted under several different protocols. Following are toxicity levels of various species.

Sheep. There are limited data available on the potential toxicity of lasalocid in sheep. To evaluate the effect of single large doses of lasalocid (51), Suffolk and Columbia ewe and wether lambs (32.66 kg average weight and 4 to 5 mo old) were split into two replicates and fed free choice alfalfa hay and mineralized salt. After adaptation (8 d), lambs were orally dosed 0, 7.5, 15, 30, 45, and 60 mg/kg BW of lasalocid. Lambs were observed for 2 to 3 h after dosing and twice daily until 30 d. One lamb died 70 h after receiving the 60 mg/kg BW dose. At 24 h, this lamb began showing signs of incoordination in the hind legs. Upon necropsy, there were no gross lesions except a watery green fluid in the digestive tract. Histological examination revealed myocarditis, myocardial necrosis, rumenitis, radiculitis, omasitis, and abomasitis. Lung congestion and edema were present. This study indicated that lambs can tolerate single doses of up to 45 times the recommended dose of 1 mg/kg BW (51). Lasalocid has a wide margin of safety in sheep. Foreyt (34) showed that feeding lasalocid at levels up to 90.7 g/ton, which exceeded three times the recommended level of 30 g/ton, for 103 d produced no adverse effects on lambs. Lasalocid did not adversely affect growth, feed intake, or feed conversion.

Cattle. Lasalocid has been tested to determine its toxicity and safety in cattle. Preliminary studies by Galitzer et al. (37) with cattle given a single oral dose (SOD) of 10 to 125 mg lasalocid/kg BW produced a toxic syndrome similar to that caused by monensin, but required a greater dose. The earliest toxic signs of lasalocid appeared in the

first 24 h after dosing. The signs were muscle tremors in the flank, increased heart and respiratory rates, and anorexia. These effects began at doses of 50 mg/kg BW and were transient. Higher doses increased the duration of toxic effects. At lower doses (10 to 25 mg/kg BW) the cattle were anorexic for 2 to 3 d and had watery diarrhea from the second day lasting up to 5 d. At these lower doses there were no other effects. Galitzer et al. (37) further concluded that lasalocid was lethal at 50 and 100 mg/kg BW. Deaths occurred between 2 and 22.5 d after the 50 mg/kg BW dose. At 100 mg/kg BW, toxicity was more acute with death occurring within 1 to 2 d of dosing. Galitzer et al. (38) reported that the physical signs and pathophysiology developing from lasalocid exposure support the hypothesis that the toxic syndromes of monensin and lasalocid are similar. All the cattle that died of lasalocid and monensin toxicoses were necropsied. These animals showed gross and microscopic lesions consistent with cardiomyopathy. Dilated heart or petechial and ecchymotic hemorrhages were observed with both drugs. Microscopically, multifocal areas of myocyte necrosis were observed. Cattle that died within 3 d of dosing with either drug had a marked degranulation of pancreatic acinar cells. Changes were not observed in any other tissues (39).

Novilla (69) indicated that monensin, lasalocid, salinomycin, and narasin are carboxylic ionophores intended for use as anticoccidial drugs for poultry and as growth promotants for ruminants. Generally, ionophores have been found safe and effective in the target animals receiving recommended dosage levels. However, toxic syndromes can result from overdosage and misuse. More information and reports of adverse reactions are available for monensin than any other ionophore because of monensin's longstanding and

widespread use in the poultry and livestock industries. Care must be exercised in the diagnosis of ionophore toxicoses since clinical signs and lesions are not pathognomonic. However, a feed-related problem characterized clinically by anorexia, diarrhea, dyspnea, ataxia, depression, recumbency, and death, and pathologically by focal degenerative cardiomyopathy, skeletal muscle necrosis, and congestive heart failure may warrant a presumptive diagnosis of ionophore toxicity. Confirmatory diagnosis will require considerations of differential diagnoses and laboratory assays to determine the specific ionophore involved. Presently, there is no antidote or treatment for toxicoses induced by ionophores. Judicious use, avoidance of overdosing, and adherence to species recommendation will help prevent the occurrence of adverse effects associated with this class of compounds (69).

Environment

Test results (51) have shown no adverse effects of lasalocid on germination or growth of corn, soybeans, cucumbers, barley, tomatoes, and ryegrass occurred when (a) litter from chickens fed lasalocid at 68 and 136 g/ton was applied on the plants, or (b) feed containing lasalocid at 136 g/ton was added to the soil. Also, the growth of seedling tobacco plants was not adversely affected when the same procedure was used.

Other Uses of Ionophores

Acute Bovine Pulmonary Emphysema. Acute bovine pulmonary emphysema (ABPE) and edema is a noninfectious respiratory distress syndrome that affects adult beef cattle after a move from dry to lush pastures (22). Blake and Thomas (12) pointed out that

ABPE was first recognized in Canadian cattle by Schofield in 1948, and has since been reported widely in the USA, England, and the Netherlands where it is called "fog fever." In Utah, it reaches epizootic proportions in autumn. Blake and Thomas (12) stated the approximate incidence in Utah per year is 1000 cattle, most of which die. Acute bovine pulmonary emphysema has reduced the productivity and profitability of beef production and has been documented for over 150 yr throughout the world. Effective prevention depends on an understanding of the cause and knowledge of the mechanism of action of the causative agent. It has been shown that an oral dose of L-tryptophan (TRP), a naturally occurring amino acid and constituent of forage, causes ABPE in cattle (45). An experimental approach and a new hypothesis was used to study this disease. Carlson and Breeze (18) indicated that ABPE results from ruminal conversion of TRP in lush forage to 3-methyl indole (3MI). 3-methyl indole is absorbed from the rumen and metabolized to a highly reactive compound that interacts directly with lung cells, causing toxicity. Fluid and air accumulation and other changes result in clinical signs of respiratory distress. Death may occur. The most promising means of prevention involves a combination of management schemes and antibiotic supplementation to inhibit ruminal 3MI formation. Management procedures should emphasize a gradual grazing transition in both the amount and composition of forage consumed. Polyether antibiotics such as monensin and lasalocid are effective in lowering ruminal 3MI concentrations and preventing ABPE in experimental situations (18). Hammond and Carlson (46) introduced a closed-system, in vitro ruminal fermentation technique that was used to screen 27 compounds for their ability to reduce the conversion of TRP to 3MI. Several compounds tended to reduce

3MI production at both 25 and 5 μg/ml. Desoxysalinomycin, X-206, chloral hydrate, nigericin, lasalocid, monensin, narasin, and salinomycin all reduced 3MI production by more than 80% at 5 μg/ml without reducing total VFA production. All of these compounds, except chloral hydrate, are polyether ionophores. Evidence suggests that these compounds may also be effective in field situations. Treatment of severely affected animals is unrewarding; the excitement and exercise associated with treatment can precipitate collapse and death. Roberts et al. (76) found the morbidity rate in ABPE to be about 10 percent. Case mortality rate varied between 5 and 20 percent.

Fly Control. The face fly (*Musca autumnalis DeGeer*) and horn fly (*Haematobia irritans L.*) are the two most important ectoparasites of grazing cattle. Although both flies require fresh cattle feces to develop, the adults attack cattle differently. The horn fly pierces the skin to suck blood and may feed from 24 to 38 times a day (48). The fly causes severe irritation and annoyance and is suspected of transmitting anthrax (63). Effective horn fly control has been shown to improve calf weight gains (17, 59). Face flies do not have mouthparts capable of piercing the skin of their host. Therefore, they feed on moist mucus or ocular secretions. Feeding around the eye contributes to eye disorders. Gerhardt et al. (40) and Shugart et al. (85) found a positive relationship between the incidence of bovine keratoconjunctivitis (pinkeye) and the number of face flies on cattle. The face fly is also the intermediate host and vector of *Thelazia* spp. eyeworm (21). Control of these flies, especially the face fly, has been difficult. Several control methods have been investigated.

One such study, conducted in Kentucky, involved four groups of eight Hereford and

Hereford crossbred steers to monitor the efficacy of monensin as a feed additive that would reduce populations of face fly and horn fly. Groups were assigned randomly to 3-ha grass-clover pastures. Two groups were supplemented with 1.1 kg ground corn/head daily (untreated), while the remaining groups were given 1.1 kg ground corn containing 100 mg monensin for 14 d and 200 mg monensin/head daily for the remainder of the 112-d trial. Fresh feces were collected from four steers in each group and bioassayed for newly hatched face fly and horn fly larvae. Fly mortality occurred in the larval stages, and bioassay from feces from cattle given monensin at 200 mg/head daily showed an average of 19.9 and 23.3% fewer ($P < .01$) face fly and horn fly pupae, respectively, compared to feces of the untreated cattle. Surviving face fly and horn fly pupae were smaller ($P < .01$) than the untreated pupae (15). Broce et al. (15) showed that additions of lasalocid directly to the dung in concentrations of 41 μg/g or greater caused significant reductions in puparial physical characteristics as well as survival. Reductions in survival ranged from 20% at 41 μg/g to 98% at 208 μg/g. Similarly, length and weight of pupal exuviae were reduced 1.5 and 3.9 times, respectively, for larvae reared at the 167 μg/g level. The toxicity observed at this level was related to changes in physical and chemical properties of the cattle feces, including a twofold increase in all organic acids measured: acetic (2.2 times), butyric (3.0 times), propionic (2.4 times), and lactic (1.6 times). Increases in organic acid levels were associated with a decrease in pH and increases in osmolality.

Herald et al. (49) stated that this is no evidence as to the mode of action of monensin against either the face fly or horn fly. Since higher levels of propionic acid are produced in the rumen of cattle given monensin, it is possible that this alters the chemical composition

of the feces to the extent that nutrients required by the larval stage of these two flies are being reduced or destroyed. The LD_{50} of the face fly and horn fly are 10.71 and 24.71 ppm, respectively, of lasalocid.

Benefits in Early Puberty. The importance of age at puberty has been stressed by Arije and Wiltbank (2). Age at puberty is influenced by genetics, level of nutrition (8), and prepuberal gain (57). Restricting energy intake in swine increases the age at puberty (44) and reduces the ovulation rate (83). It has been shown that monensin may affect reproductive performance by reducing the postpartum interval in mature cows (90) and by reducing the age at puberty in heifers (64). Rhodes et al. (74) indicated that when a substantial portion of dietary energy bypassed the rumen in the form of protein encapsulated fat, thus decreasing the proportion of readily fermentable carbohydrate in the rumen, age at puberty was increased even though the heifers fed the protein encapsulated fat gained more and became fatter.

Because the primary effect of monensin appears to be that of increasing the ruminal production of propionic acid at the expense of acetic and butyric acid (28, 73), it would seem desirable to confirm the effect of monensin on age at puberty and to determine if the effects of monensin on puberty seen by Moseley et al. (64) could be duplicated by altering propionate production by shifting hay and grain ratios in the diet of heifers of equal age, live weight, live weight gain, and fatness. McCartor et al. (62) found that there was a difference ($P < .009$) in age at puberty with the control having a mean age at puberty of 514 d and the treatment group having a mean age of 485 d. Weight at puberty was likewise reduced ($P < .03$) when treatment was compared to the control. While the cause

of this response is not totally clear, propionate infusion studies (79) into prepuberal heifers indicated release of luteinizing hormone resulting from a gonadotrophin-releasing hormone challenge.

Neuendorff et al. (68) reported the effects of lasalocid on growth and puberal development in Brahman bulls. They concluded that bulls fed lasalocid at 200 mg/hd/d exhibited a greater growth in scrotal circumference, had higher testicular volume, and reached puberty at an average of 30 d before control bulls ($P < .06$). Ages and weights at the first detected sperm cell and at puberty for the Brahman bulls used in this study are also in close agreement with those reported by Stewart et al. (87) for Brahmans at first sperm and by Fields et al. (32) for Brahmans at puberty.

Protein Sparing. Several cattle studies have suggested that monensin may reduce the dietary protein requirement (24, 61). Because of these studies, there has been considerable interest in the effect of monensin on intraruminal nitrogen (IRN) metabolism. This effect was documented by the evidence of decreased ruminal ammonia (NH3-N) when either lasalocid or monensin was incorporated into the diet. Feeding ionophores would therefore increase the quantity of dietary protein not available for degradation and should make this escaped protein available for digestion and absorption in the small intestine (72). Hoffmann-La Roche (51) showed that Russell summarized the amino acid sparing effect of ionophores. He concluded that because ionophores have little effect on proteolysis, the term "amino acid sparing" is a more correct description than "protein sparing" regarding the action of ionophores on protein degradation.

The benefit of this phenomenon is understandably related to the animal diet. Efficient

feed utilization by the ruminant animal represents a balance between fermentation and passage of the fermented end products as well as undigested feed nutrients from the rumen. The response from ionophore use relating to amino acid sparing should be most evident when the diet is marginal or low in crude protein. Research (7) has demonstrated greater nitrogen retention due to feeding monensin to steers receiving a protein deficient diet, and monensin caused a greater animal performance response with steers fed low protein diets (47). The review of literature strongly suggests that lasalocid and monensin do exhibit an amino acid sparing effect by making more effective use of amino acid nitrogen. This amino acid sparing is twofold. First, dietary proteins are very soluble in the rumen. However, with the addition of lasalocid to the diet, this alters the microbial population in the rumen and reduces the degradation of soluble protein. Second, propionic acid and amino acids are the animal's only two sources that are gluconeogenic. This means that the animal can take these two products and convert them into glucose as an energy source for the animal. Adding lasalocid to the diet, and altering the microbes within the rumen, causes an increase in propionic acid production. With this increase in propionic acid, less energy waste of amino acids will occur and more amino acids will reach the small intestines for better utilization.

Feed Efficiency and Rate of Gain. Lasalocid and monensin were fed to feedlot steers at 0, 20, or 30 g/ton for 119 d. Owens and Gill (71) reported that rate of gain tended to be greater with the highest level of lasalocid than with the highest level of monensin. Feed intake was reduced by 4.1% with lasalocid and 2.0% with monensin. Efficiency of gain was improved by 5.9% with the addition of either drug, and was slightly greater (7.6% vs

4.3%) with lasalocid than monensin. Calculated metabolizable energy was increased with either drug (3.8%) and greater with lasalocid than monensin (5.1% vs 2.4%). Fecal starch tended to be lower with lasalocid than with monensin feeding. Back fat thickness tended to be lower with ionophore feeding and the percentage of carcasses that graded choice was significantly greater for steers fed lasalocid than those fed monensin due to slightly higher marbling scores. Results indicated that lasalocid increases efficiency of feed use by feedlot steers to a level equal to or greater than monensin. The lower feeding level (22 ppm) proved to be equally effective with the higher level of either drug (71).

Current USDA Clearances

The goal of drug manufacturers, the Food and Drug Administration, the feed industry, and animal producers has long been to efficiently produce a safe, animal-based, food supply. A safe food supply and efficient production of healthy animals is in the best interest of participating industries as well as the consuming public. The Food and Drug Administration has several approval requirements before permitting addition of any medication to animal feed. Table 2 lists the species and amounts that have been approved by the FDA for use of Lasalocid in feed mixes. For further information regarding combination of feeds or drugs, refer to the Feed Additive Compendium (30).

TABLE 2. FDA approval for lasalocid on various species of animals.

ANIMAL	DRUG	USE LEVEL	INDICATIONS FOR USE
Chickens (broilers or fryers)	Lasalocid Sodium	68-113g/ton	For the prevention of coccidiosis caused by *Eimeria* spp. in broiler or fryer chickens only.
Cattle	Lasalocid	10-30 g/ton in complete feed. Feed continuously to provide not less than 100 mg nor more than 360 mg of Lasalocid per head per day.	For improved feed efficiency in cattle fed in confinement for slaughter.
	Lasalocid	25-30g/ton in complete feed. Feed continuously to provide not less than 250 mg nor more than 360 mg of Lasalocid per head per day.	For improved feed efficiency and increased rate of weight gain in cattle fed in confinement for slaughter.
	Lasalocid	Feed continuously at a rate of no less than 60 mg nor more than 200 mg of Lasalocid per head per day. Hand fed: The drug must be contained in at least 1 lb of feed.	For increased rate of gain in pasture cattle (slaughter, stocker, feeder cattle, dairy and beef replacement heifers).
	Lasalocid	1mg/2.2 lb (1.0 kg) of bw maximum of 360 mg/hd/d. Feed continuously, up to 800 lb bw (360 kg).	For control of coccidiosis caused by *Eimeria bovis* and *Eimeria zuernii*.
Sheep	Lasalocid	20-30g/ton in complete feed. Feed continuously to provide not less than 15 mg nor more than 70 mg of Lasalocid per head per day depending on bw.	For the prevention of coccidiosis caused by *Eimeria ovina, Eimeria crandallis, Eimeria ovinoidalis, Eimeria parva* and *Eimeria intricata* in sheep maintained in confinement.

MATERIALS AND METHODS

Thirty-six multiparous Holstein cows were assigned to the study. Twelve cows were randomly assigned to each of three levels of dietary lasalocid: 0, 180, or 360 mg/hd/d. Cows were placed on the dietary treatment 1 wk after calving and remained on the treatment for a 10-wk lactation period. The basal diet was composed of ground corn, alfalfa hay, alfalfa haylage, corn silage, and soybean meal (Table 3). The basal diet was fortified with vitamins and minerals to meet recommended levels (70).

Animals were housed together with individual free stalls. Bedding was changed on an as-needed basis with cereal straw. Basal diet was individually offered as a total mixed ration via Calan gates on an ad libitum basis with a 5-10% refusal rate per day. Calan gates were labeled and color coded as to treatment to avoid mix-up on control and treatment cows. Daily ration was offered in two equal portions at 0500 and 1700 h. Enough basal diet was mixed to last only for a 2 d period to avoid spoilage due to feed moisture content. Lasalocid treatments were administered with .5 kg of ground corn at each of the daily feedings by hand-mixing with the basal diets. Control animals were also offered .5 kg of ground corn at each of the daily feedings to maintain consistency among the diets. Samples of basal diet were taken daily and composited by week. Diet samples were dried in a forced-air oven at 60^{0}C for 72 h. Dried samples were then ground to pass a 1-mm screen and analyzed for laboratory DM (105^{0}C for 8 h), CP (43), ADF, NDF (56), and macro minerals (inductively coupled plasma, Thermo Jarrell-Ash ICAP 9000). Refusals were weighed and sampled daily, with samples proportionately composited by

week. Composites were analyzed similar to diet samples. Concentration of ADF in refusals was used to determine if cows were preferentially consuming concentrate or forage as an indicator of acidosis.

Milk production was recorded by electronic flow meters (BouMatic System, Madison, WI). Milk samples were taken four times each week (Monday PM, Tuesday AM, Thursday PM, Friday AM). Milk samples were analyzed for fat, protein, and somatic cells using standardized procedures by the Utah Dairy Herd Improvement Association (DHIA) laboratory, Logan, Utah. Milk samples were pooled according to production and cholesterol was analyzed by Hurst et al. (53).

Blood samples were harvested either coccygeal or jugular venipuncture thrice weekly (Monday, Wednesday, and Friday) prior to AM feeding to reduce variability. Jugular venipuncture was the secondary cite used in case the coccygeal cite was unable to be reached. Plasma was composited weekly and retained at -20^{0}C for subsequent analyses. Blood metabolites including glucose, nonesterified fatty acids, and β-hydroxybutyrate were analyzed by Sigma kit No. 315 (Sigma Chemical Co., St. Louis, MO); Acyl-coenzyme A synthetase- acyl-coenzyme A oxidase- peroxidase assay (Wako Chemicals USA, Inc., Dallas, TX); and Williamson and Mellanby (92) Acetoacetate and β-hydroxybutyrate (pg. 454: in Methods of Enzymatic Analysis); respectively.

Cows were weighed each Friday before the 0500 h feeding. Body condition scores were assigned to each cow at that time by three independent evaluators. The average of the three scores was reported. Scoring was on a scale of 1-5, with 1 being extremely thin

TABLE 3. Actual ingredient and nutrient content of basal diet (dry matter basis).

Ingredients	Composition %
Alfalfa haylage	20.08
Corn silage	13.85
Alfalfa hay	14.53
Ground corn	38.75
Soybean meal	11.45
Dicalcium phosphate	.85
Vitamin-mineral mix[a]	.85
Nutrients	
Crude protein	16.47
Acid detergent fiber	30.82
Neutral detergent fiber	40.54
Calcium	.80
Phosphorus	.29
Potassium	1.65
Magnesium	.27
Sulfur	.15

[a] Vitamin A, 767.30 kiu/kg; Vitamin D, 76.73 kiu/kg; Vitamin E, 1800 iu/kg; Zn, 2400 ppm; Mn, 2000 ppm; Cu, 600 ppm; I, 24 ppm; Co, 6 ppm; Se, 12 ppm.

and 5 being extremely fat. Health status was observed daily. Any illness was reported to a qualified veterinarian for diagnosis and treatment.

The ANOVA model used was a repeated measures design analyzed in a split-plot arrangement. Lasalocid was used as the main plot and the error term was cows within treatments. Repeated weekly measurements were used as the subplot and the residual

error was used to test week and week × treatment interactions. Cow performance during the previous lactation was used as a covariate in analyzing the data. Linear contrasts were used to evaluate differences among the control and treatment groups.

RESULTS AND DISCUSSION

Lasalocid treatment tended (P = .13) to increase milk production by 7.8%, or approximately 2.6 kg/hd/d (Table 4). Fat and protein composition of the milk was not changed, so fat-corrected milk followed the same trend. An effect due to level of lasalocid was not detected among treatments. Somatic cell count of the milk was not affected by lasalocid or by lasalocid level. These somatic cell counts are considered low according to DHIA standards. Cows were apparently not challenged by mastitis.

TABLE 4. Effects of dietary lasalocid on performance of dairy cows during early lactation.

	mg Lasalocid/hd/d				
Item	0	180	360	SEM[a]	P>F[b]
Daily milk, kg/d	33.50	36.00	36.10	1.19	.13
Milk composition					
Fat, %	3.74	3.53	3.87	1.05	.84
Protein, %	2.96	2.87	3.00	.43	.29
Somatic cells[c]	111.10	216.20	82.20	162.70	.17
DM intake, kg/d	22.00[d]	21.50[e]	21.20[e]	.24	.02
Mean BW[f], kg	607.60	615.80	618.30	17.10	.89
Body Condition[g]	2.96	2.96	3.07	.19	.90
Milk: DM ratio[h]	1.52	1.67	1.70	.61	.08

[a]Standard error of mean.
[b]Probability greater than F score.
[c]x 1000
[d,e]Means in the same row with different superscripts differ (P < .05).
[f] mean of ten weekly weights.
[g]1 = extremely thin, 5 = extremely fat, mean of ten weekly scores.
[h] kg milk per kg of DM consumed.

Dry matter intake was reduced approximately 3% by dietary lasalocid but was not affected by level of lasalocid. Although this is not a consistent observation with ionophore use, it has been reported in many studies in beef cattle fed similar diets (5, 89). As a result of the reduction in DMI and the trend for increased milk production, efficiency of milk production (kg milk per kg of DM consumed) tended to be improved by lasalocid (P = .08), but was not affected by level of lasalocid. The literature is replete with reports of ionophores improving feed efficiency and rate of gain in ruminants fed high-concentrate (11, 14, 16) and high-roughage diets (42, 86, 89). This observation was mainly due to increased ruminal propionate production and/or decreased ruminal degradation of dietary protein (81). Although the basal diet was adequate in CP, much of it was from highly degradable sources, i.e., alfalfa and soybean meal (70). Reduction in ruminal degradation of dietary proteins would likely increase the amino acid supply to the duodenum, which may account for the trend toward increased milk production. Although increased ruminal propionate production would increase the energetic efficiency of cattle, high propionate production is linked with milk butterfat depression. Since milk butterfat was not reduced, high propionate production is not likely to have been an important factor.

Body weight and body condition were not affected by lasalocid treatment (P = .89, .90 respectively). Both variables were acceptable for dairy cows during early lactation.

Feeding practices that are insufficient to meet energy requirements for high milk yield may lead to negative energy balance, increased fat mobilization, and increased hepatic ketogenesis (3). Detilleux and Gröhn (27) indicated that older, high-yielding cows may not be able to metabolize energy efficiently enough to support prioritized demands for

high milk yield and, subsequently, may develop ketosis.

Blood metabolite concentrations, including glucose, nonesterified fatty acids, and β-hydroxybutyrate, were used to indicate an increase or decrease in ketosis among lasalocid treatments. Higher blood glucose levels are a good indicator of subclinical ketosis. Increased levels of β-hydroxybutyrate indicate that there is fat being mobilized from adipose tissues, indicating that dietary energy is deficient and perhaps the animal is unable to efficiently utilize the energy being mobilized from fat stores, thus creating a ketotic environment for the animal. Glucose, nonesterified fatty acids, and β-hydroxybutyrate were unaffected by lasalocid (P = .95, .56, and .64, respectively) and all fall within normal ranges. This would indicate that in this study the energy requirements for early-lactating cows were being met, or that lasalocid had little or no effect on blood metabolite concentration in early-lactating cows.

TABLE 5. Effects of dietary lasalocid on blood metabolites of dairy cows during early lactation.

	mg Lasalocid/hd/d				
Items	0	180	360	SEM[a]	P>F[b]
GLU[c] mg/dL	69.04	68.61	68.81	2.95	.95
NEFA[d] μeq/L	230.87	233.13	226.74	13.31	.56
BHA[e] mg/dL	5.37	5.47	5.25	.44	.64

[a]Standard error of mean.
[b]Probability greater than F score.
[c]Glucose
[d]Nonesterified fatty acids
[e]β-hydroxybutyric acid

IMPLICATIONS

The poultry and beef cattle industries have greatly benefitted from the use of ionophores, both in terms of health and production. The results of this study indicate that lactating dairy cows may benefit from the use of lasalocid in terms of milk production and the efficiency of milk production.

With the costs of producing milk always on an increase and producers wanting to keep costs down, there can be an economic benefit to them in terms of increased milk production and decreased DMI. In addition to the economic benefits, the feeding of lasalocid promotes better utilization of feed nutrients and increased animal health.

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