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Review

Effect of Ionophores on Metabolic Energetics in Cattle

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ABSTRACT

Monensin caused a shift in acetate to propionate ratio which improved the energy utilization efficiency of the ruminant animals. It maintained a higher ruminal pH and affected end products of ruminal fermentation by selecting a monensin tolerant microbial population which produced more propionate, less acetate, butyrate, lactate and methane. Monensin enhanced feed digestibility; however, level of forage intake, ruminal fill and particulate and fluid rates of passage may be important determinants. Monensin fed with good quality forages decreased intake, an effect similar to monensin fed with concentrate feeds. Thus, it improved metabolic efficiency when high quality forages were fed, thereby reducing the quantity of forage required to satisfy the animal's energy requirement. Therefore, intake was not restricted by a limitation in gut fill. Monensin improved weight gain response in pasture cattle by providing more net energy (NE) per unit feed consumed. However, as forage quality increased, expected gain response was reduced as growth approached the ruminant's genetic potential. The lasalocid increased molar proportion of propionate and declined molar proportion of acetate and butyrate and improved feed efficiency (FE) both by increasing metabolizable energy (ME) density of the diet and reducing feed intake. Reduced intake is a consequence of an increase in NE for maintenance whereas NE for gain is not affected. Improvements in nitrogen (N) retention with lasalocid cannot be explained by a change in microbial affinity for protein substrates and further studies are needed on this aspect.

Key Words: Ionophores; Metabolic energetics; Cattle

Ionophores are a group of biologically active molecules capable of stoichiometrical interaction with metal ions, forming a complex which then serves as a carrier to transport complexed ions across biomolecular lipid membranes (Ovchinnikiv, 1979). Ionophores form lipid soluble complexes with certain cations and facilitate their transport across biological membranes (Pressman, 1976). Ionophores reduced ruminal methane losses (Richrdson *et al.,* 1976), but did not influence ruminal digestion of starch in cattle fed steam flaked corn based diets (Zinn, 1986). The influence of ionophores on protein escaping ruminal degradation appears to increase with increasing protein solubility (Tolbert *et al.,* 1977; Dinius *et al.,* 1976). The steam flaking process also reduced methane losses (Johnson *et al.,* 1968), possibly raising the baseline for the ionophore effect.

The efforts to produce efficient and cost effective human foods from animal sources has stimulated continued research for suitable combinations of known nutrients for new additive which will increase the efficiency, growth rate and the production level of animals. These widespread efforts have led to the present use of antibiotics, hormones and other chemicals in animal production. Ionophores, like lasalocid and monensin incorporated into various supplements alter ruminal fermentation, promote efficient utilization of forages and subsequently improve livestock productivity. Little is known, however, about the mechanisms through which such supplementation practices affect the energetic efficiency of ruminants. A complete understanding of these mechanisms would not only allow for refinement of existing management practices but will also help in developing new practices which consequently can improve the productivity of livestock. The objective of this paper, therefore, is to evaluate the influence of monensin and (or) lasalocid supplementation on intake, ruminal characteristics, digesta kinetics and digestibility in relation to animal performance.

Feed Consumption

Goodrich *et al.* (1984) reported reduced dry matter (DM) intake and a significant improvement in FE in animals fed monensin containing diets when compared to those fed control diets. This improved FE may be due to monensin which has increased apparent maintenance energy efficiency by 7.5% (Byers, 1980). This improved energetic efficiency of feed can satisfy maintenance requirements of animals at lower DM intake and greater proportion of feed energy will go for productive purposes, resulting into enhanced productivity from the animals. Lemenager *et al.* (1978) reported 15.6% decrease in forage intake by cattle fed diets containing monensin. This might be due to slower ruminal fluid and particulate turnover rates by 30.8 and 43.6%, respectively in steers fed monensin and a low quality harvested forage. A decrease in rumen turnover rate in animals supplemented monensin while grazing forage caused an increase in fiber digestibility (Ellis *et al.*, 1983).

Gutierrez *et al.* (1982) reported that lasalocid increased FE and reduced feed intake in growing cattle fed sorghum silage based diets. An inconsistent effect of varying levels of lasalocid on weight gain, feed intake and FE has been reported in steers fed alfalfa cubes (Thonney *et al.*, 1981). Lasalocid supplementation improved forage utilization characteristics in steers grazing similar pasture (Jacques *et al.*, 1987). Zinn (1987) found that lasalocid supplementation resulted in reduced feed intake (12.3 and 6.5% in feedlot steers). Feed conversion was improved 5% by the inclusion of ionophores in the diet (P<.01).

Ruminal Characteristics

Monensin has produced variable responses in ruminal pH of cattle fed forage diets. Horn *et al.* (1981) reported a higher ruminal pH in steers grazing on pasture fed 200 gm monensin per hour daily (6.75 vs 6.22) when compared to steers fed no monensin. In other studies with cattle fed primarily forage diets, monensin supplementation did not affect ruminal pH (Dinius *et al.*, 1976; Poos *et al.*, 1979; Thonney *et al.*, 1981). However, monensin maintained a higher ruminal pH and prevented lactic acidosis in cattle subjected to acute carbohydrate stress (Dennis *et al*, 1980). In a subsequent study, monensin fed animals had lower ruminal lactate concentrations than controls as a result of selective inhibition of lactate producing bacteria (Dennis *et al.*, 1981). Burrin *et al.* (1988) conducted two finishing trials to measure the response of cattle adjusting to high concentrate diets to three different (0,11,33 mg/kg) dietary monensin levels. Increasing the level of monensin reduced grain adaptation period and both FE and weight gain were increased. Feeding monensin during grain adaptation also improved intake patterns, these effects were not manifested in total finishing performance.

Horn *et al.* (1977) reported 15% decrease in methane production in steers fed monensin grazing wheat pasture while *in vitro* studies with monensin have demonstrated decreases in methane production by 13% (Bartley *et al.*, 1996) and 21% (Chalupa *et al.*, 1980). Van Nevel and Demeyer (1977) concluded that the antimethanogenic property of monensin was not the result of a direct toxic action against methanogenic bacteria. Rather, the methane production was restricted from limited availability of free ruminal CO_2 and H_2 from metabolic inhibition of bacteria capable of forming and decomposing formate.

Several researchers (Horn *et al.*, 1977; Poos *et al.*, 1979; Sakauchi & Hoshino, 1981) have investigated the effect of monensin on ruminal N metabolism and have demonstrated depressions in ruminal ammonia concentration by monensin, indicating that monensin depresses deamination and (or) proteolysis of dietary protein. Lasalocid had been shown to have affinities for a number of cations including K, Na, Ca and Mg (Pressman, 1976). It has also been shown to increase molar proportion of propionic acid with a decline in molar proportion of acetate and butyrate production in the rumen (Richardson *et al.*, 1976; Thorton *et al.*, 1976). The shift in VFA production in the rumen improves FE and reduces feed intake without adversely affecting rate of gain in feedlot cattle and sheep (Bartley *et al.*, 1970; Berger *et al.*, 1998. A reduction in methane production has been reported in *in vitro* studies with lasalocid (Bartley *et al.*, 1979), but *in vivo* measurements are lacking. Feeding lasalocid decreased (P<.05) blood urea-N in comparison with control in pregnant ewes (Thomas *et al.*, 1988).

Digestibility

In vivo studies (Dinius *et al.*, 1976 ; Thorton & Owens, 1981; Faulkner *et al.*, 1985) have observed negligible to marginal changes in diet digestibility with monensin, whereas *in vitro* studies (Henderson *et al.*, 1981; Wallace *et al.*, 1981) have shown depressions in fiber digestibility. The reduced digestibility in *in vitro* studies may be attributed to the excessive accumulation of the end products of fermentation, inhibiting the microbial activity, whereas in *in vivo* studies the fermentation end products do not accumulate because of the continuous absorption of these from the rumen into the blood. Dinius *et al.* (1976) observed that *in vivo* digestibilities of DM, crude protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose and cellulose were unaffected by monensin fed in forage to steers at levels of 1, 11, 22 and 33 mg/kg DM. Ricke *et al.* (1984) reported no influence of lasalocid or monensin on DM, NDF and ADF digestibilities in sheep fed an alfalfa corn diet. However, absorbed N was increased (P<.05) with lasalocid, but not with monensin. Limited data are available concerning the addition of lasalocid to roughage based diets.

Growth Performance

Monensin has been used for many years as a feed additive to improve FE and average daily gain (ADG) in feedlot cattle. Potter *et al.* (1976) and Raun *et al.* (1976) showed improvements in both ADG and FE in cattle fed diets containing monensin. Raun *et al.* (1976) reported a 17% improvement in FE in feedlot cattle consuming diets of 60 and 85% concentrate containing 33 mg monensin/kg feed. Potter *et al.* (1976) reported increased ADG by 17% in cattle fed forage diets containing 200 mg monensin/kg feed DM when compared to cattle fed diets containing no monensin. Similarly, supplemental monensin increased ADG in calves grazing dormant winter pasture (Males *et al.*, 1979) or low quality coastal Bermuda grass pasture (Oliver, 1975).

Goodrich *et al.* (1984) summarized data from 225 feedlot trials involving 11,274 heads of cattle fed either control or monensin containing diets. The cattle fed diets containing monensin across all trials exhibited on an average 1.6% increase in ADG, 6.4% decrease in feed consumption and 7.5% improvement in FE. Goodrich *et al.* (1984) also Summarized data from 24 trials for cattle consuming pasture or harvested forage and reported that monensin fed cattle exhibited a 13.1% (0.61 vs 0.69 kg/d) increase in ADG over controls. This increased weight gain in cattle may be attributed to the monensin altered ruminal VFA proportions. Generally, molar proportions of acetate and butyrate are decreased with a consequent increased proportion of propionate (Richardson *et al.*, 1976) which tend to increase the efficiency of energy utilization. By increasing propionate at the expense of acetate and butyrate, monensin theoretically increases efficiency of converting feed energy to energy in the form of VFA (Van Maanan *et al.*, 1978). They also investigated effects of monensin on blood glucose kinetics in cattle fed either high forage or high concentrate diets. An increase in ruminal propionate production of 50 and 75% was followed by increase in net glucose synthesis of 7% and 16% for high forage and high concentrate diets, respectively.

Lasalocid is a carboxylic ionophore that improved FE and rate of gain in ruminants fed high roughage diets (Thonney *et al.*, 1981; Spears & Harvey,1984) and high concentrate diets (Brethour, 1979; Brown & Davidovich, 1979; Berger *et al.*, 1981) Delfino *et al.* (1988) quantified the effects of lasalocid on the performance and energy partitioning of cattle fed a 90% concentrate, barley based diet and reported that lasalocid fed heifers gained an avenge of 1.35 kg daily, whereas control heifers gained 1.24 kg. No difference (P<.10) in FE among heifers fed lasalocid, or control diets was observed and ionophores had no influence on carcass quality. The NE for maintenance was increased (P<.05) by 10 to 21% with lasalocid, whereas the NE for gain value was not affected. Average heat productions of the steers were increased (P<.05) by 7% with lasalocid. It was concluded that the main method by which lasalocid improved feed conversion was by increasing by ME density of the diet. Lemarie *et al.* (1987) reported a slight increase (P<.08) in daily gain and feed:gain ratio with lasalocid addition in lambs fed corn, oats, soybean meal and cottonseed hulls.

Mode of Action

The mode of action of lasalocid appears to be similar to monensin (Chen & Wolin, 1977; Dennis *et al.*, 1981) where selection occurs for an ionophore resistant rumen microbial population of succinate producers and lactate fermenters capable of producing more propionate and less acetate, butyrate and methane (Ricke *et al.*, 1984). Major effects of monensin in the rumen are attributable to alterations in transmembrane ion flux and dissipation of cation and proton gradients within different species of ruminal bacteria.

CONCLUSIONS

The monensin increased both ruminal propionate production and the pace of gluconeogenesis which conserved protein and other substrates, alternatively used for gluconeogenesis. This resulted into improved FE and growth in ruminants. Increased glucose production from monensin provided more substrate for glycolysis which allowed a possible bioenergetic advantage to the ruminant. Depressions in ruminal ammonia concentration by monensin and consequences of this effect on growth and FE in ruminants depend on the nature of the diet and the amount of dietary protein escaping ruminal degradation.

Lasalocid reduced methane production by its selective action against ruminal microbes. Succinate producer and lactate fermenter ruminal microbes escaped lasalocid action and thus produced more propionate consequently less acetate, butyrate and methane. These chemicals prevented lactic acidosis and no change in diet digestibility was reported.

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