AMMONIUM PROPIONATE AND AMMONIUM LACTATE AS NITROGEN SOURCES FOR LACTATING DAIRY COWS

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ABSTRACT

AMMONIUM PROPIONATE AND AMMONIUM LACTATE AS NITROGEN SOURCES FOR LACTATING DAIRY COWS

By

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Four isonitrogenous concentrates using soybean meal, urea, ammonium propionate or ammonium lactate as supplemental nitrogen sources were fed to 36 cows (9 per treatment) at 1 kg per 2.5 kg milk for 84 days. Each cow's concentrate was mixed with sufficient corn silage to yield a 10% refusal of the complete feed. Rations were fed once daily. Intakes of urea, ammonium propionate, and ammonium lactate were 209, 1170, and 1151 g per day, respectively.

Milk yields and composition were adjusted by co-variance using means of a 14-day standardization period. For soybean meal, urea, ammonium propionate, and ammonium lactate, milk yields averaged 23.3, 23.0, 23.8, and 22.7 kg per day; FCM, 19.6, 22.6, 21.8, and 20.6 kg per day; milk

fat, 3.0, 3.6, 3.5, and 3.5%; and milk solids-not-fat, 8.84, 8.92, 8.99, and 8.83%. FCM was higher ($P < .05$) for NPN treatments than soybean meal. Dry matter intakes were 18.4, 18.7, 17.7, and 17.9 kg per day for the respective treatments.

Rumen ammonia and pH were higher ($P < .05$) for NPN than soybean rations. Rumen propionate was highest ($P < .01$) and acetate:propionate ratio lowest ($P < .01$) for cows fed the ammonium propionate.

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TABLE OF CONTENTS

Table of Contents (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

INTRODUCTION

The ability of the ruminant to utilize nonprotein nitrogen is becoming increasingly important for the economical production of meat and milk. Urea is the most popular source of nonprotein nitrogen because of its high crude protein equivalent and low cost. However, reduced performance is encountered when excessive urea is fed. Thus, the search continues for nonprotein nitrogen sources which will supply the required supplemental nitrogen for high levels of production in ruminants.

In vitro studies (Belasco, 1954) and feeding trials with steers (Varner and Woods, 1968, 1969, 1971; Allen *et al.*, 1972 a, 1972 b; and Allen, 1972) have shown the ammonium salts of several short chain organic acids equal or superior to urea in supplying supplemental nitrogen. Ammonium lactate is formed when ammonia is added to corn silage at the time of ensiling. Feeding ammonia-treated silage has resulted in superior performance of steers (Henderson *et al.*, 1971 a, 1971 b, 1971 c; and Henderson and Bergen,

1972) and lactating dairy cows (Huber and Thomas, 1971; and Huber et al., 1973) than urea-treated silage.

The purpose of this study was to evaluate the ammonium salts of propionic and lactic acids as supplemental nitrogen sources for lactating dairy cows and to describe the associated changes in rumen fermentation.

LITERATURE REVIEW

In Vitro Evaluation of Ammonium Salts

Early *in vitro* studies have illustrated that ammonium salts of various organic and inorganic acids have a high availability of nitrogen for rumen microflora. Belasco (1954) used an *in vitro* technique to compare various nitrogen compounds with urea. All of the ammonium salts of organic acids were equal or superior to urea in bacterial utilization of nitrogen, as measured by bacterial growth and cellulose digestion. Ammonium succinate and ammonium lactate had higher rates of nitrogen utilization and lower free ammonia levels than urea or other ammonium salts. Hudman and Kunkel (1953) used an *in vitro* technique and reported ammonium acetate to be as effective as urea for protein synthesis by rumen microorganisms. Acord *et al*. (1966) also used an *in vitro* procedure, and found the ammonium salts of sulfate, chloride, acetate, and phosphate equal to urea.

In Vivo Evaluation of Ammonium Salts

Favorable performance has been reported when ruminant animals have received supplemental dietary nitrogen as ammonium salts.

Growth

Repp et al. (1955) reported that urea, ammonium acetate, ammonium propionate, ammonium formate, and propionamide had about equal value, when replacing 50 per cent of the nitrogen in diets for growing lambs. In another trial with lambs, Moore and Anthony (1972) found several ammoniated products were more effective protein sources than urea, but less effective than cottonseed meal.

Varner and Woods (1969) reported that steers fed the ammonium salts of acetate, propionate, or butyrate as nitrogen supplements, had significantly higher rates of gain than those fed urea. Allen et al. (1972 a) comparing ammonium salts of several organic acids with urea or soybean meal, showed no differences in average daily gains of steers. However, in another trial with steers, Allen (1972) reported that cattle supplemented with ammonium acetate gained 5.4 per cent faster than cattle receiving soybean meal and 12 per cent faster than urea-fed steers. Steers fed ammonium lactate gained faster than those on soybean meal (13.5 per cent) or urea (20 per cent).

Milk Production

Work in Holland (Frens 1946) compared urea, ammonium lactate and natural protein for milk production and demonstrated that urea had 41.1 per cent and ammonium lactate 45.9 per cent of the value of an equivalent amount of natural protein. Magruder *et al*. (1951) compared ammoniated molasses with control and urea rations and found no significant differences in milk production or body weight changes. Prescott *et al*. (1969) fed a mixture of ammonium salts containing mainly ammonium acetate, to lactating dairy cows via the drinking water. Fat content was higher for the cows fed the ammonium salts than for the controls and some depression in milk yields was noted in the higher producing cows receiving the ammonium salts.

Hazzard (1958) fed an ammoniated whey product of high ammonium lactate content and reported depressed milk and butterfat, greater losses in body weight and lower intakes. Nutrient intakes were below requirements due to unpalatability; however, it was believed that the feedstuff consumed was well utilized.

Nitrogen Retention

Varner and Woods (1971) reported that steers fed soybean meal or ammonium salts retained more of their dietary nitrogen than did steers fed urea. Ammonium propionate or ammonium butyrate fed steers retained significantly more nitrogen than those fed urea (Varner and Woods, 1969 and 1971). In one study, Varner and Woods (1969) found that cattle fed ammonium acetate had significantly lower nitrogen retentions than those receiving ammonium propionate or ammonium butyrate. Allen et al. (1972 b) found no differences in nitrogen retention of steers fed soybean meal, liquid urea, 1/2 liquid urea - 1/2 corn steep water, ammonium formate, ammonium acetate, ammonium propionate, ammonium lactate, or ammonium butyrate. In a separate trial, Allen (1972) found that the urea and soybean meal supplemented steers retained significantly less nitrogen than those fed ammonium acetate or ammonium lactate.

Toxicity

Belasco (1954) in reporting *in vitro* studies with ammonium salts, suggested that an excess of ammonium salts might not be as hazardous as a similar excess of urea because of the accompanying acid radical. In toxicity trials with sheep, Moore and Anthony (1970) found ammonium acetate to be more toxic than urea, but ammonium lactate was less toxic. In a second study, Moore and Anthony (1971) again found ammonium lactate was less toxic than urea. Webb *et al*. (1972) found that smaller doses of intraruminally administered urea than ammonium acetate were required to produce toxicity in cattle.

Rumen Ammonia

In most studies, ammonium salts have resulted in rumen ammonias similar to urea and higher than soybean meal when fed to cattle. Varner and Woods (1968 and 1971) reported that feeding urea or the ammonium salts of acetate, propionate, or butyrate to steers resulted in higher levels of rumen ammonia than soybean meal. Varner and Woods (1969) found rumen ammonia for ammonium acetate to be higher than for other ammonium salts or urea. Webb *et al*. (1972) found higher rumen ammonia with intraruminally administered ammonium acetate than urea. Allen *et al*. (1972 b) noted that rumen ammonia was highest for cattle fed ammonium acetate and ammonium lactate compared to other supplemental nitrogen sources. Allen (1972) also reported that rumen ammonias were higher for steers fed urea than for those fed soybean meal or ammonium salts.

Rumen pH

Varner and Woods (1969) reported that rumen pH was significantly lower for cattle fed ammonium acetate or butyrate compared to those fed urea. Varner and Woods (1971) further reported a lower pH in rumen fluid from steers fed ammonium salts than from steers fed either urea or soybean meal. In contrast, Allen (1972 b) found that steers fed soybean meal had a lower rumen pH than steers supplemented with nonprotein nitrogen. Webb et al. (1972) found that intraruminal administrations of urea elevated rumen pH, but ammonium acetate did not.

Rumen Volatile Fatty Acids

Varner and Woods (1968 and 1971) reported total rumen volatile fatty acids (VFA) were higher for steers fed ammonium salts than urea or soybean meal. In addition, Varner and Woods (1971) and Allen (1972 b) reported that the molar concentration of a specific VFA was increased by feeding that organic acid as an ammonium salt. Allen (1972) reported that feeding ammonium acetate or ammonium propionate resulted in increased disappearance of the respective acids from the rumen and by 4 hours post-feeding, levels were lower when these salts were fed than for other nitrogen sources. Allen (1972) also found that feeding ammonium lactate resulted in elevated rumen levels of acetic and propionic acids.

Propionic Acid and Dairy Cattle Performance

In most studies, an increase in rumen propionate has resulted in a decrease in milk fat. Rook and Balch (1961) found that propionic acid infused directly into the rumen decreased the yield and percentage of milk protein and solids-not-fat. In a later study Rook et al. (1965) reported that propionic acid infusions increased solids-not-fat and casein, but again decreased fat. Fisher and Elliot (1966) were able to depress fat and increase lactose in cows' milk with intravenous infusions of propionate.

Schmidt and Schultz (1958) fed one half pound sodium propionate per day and found no significant differences in milk production, hay consumption, or body weight changes; but a slight decrease in butterfat was noted. The feeding of propionate resulted in higher levels of all rumen volatile fatty acids for the first 3 hours post-feeding, particularly propionic. McCullough et al. (1969) found that addition of sodium propionate to "all-in-one" silage rations decreased milk fat, increased solids-not-fat, and did not affect total milk production. By feeding concentrates containing one per cent urea and increasing levels of propionate, Jones (1971) failed to detect a decrease in milk fat.

Both intraruminal infusion (Montgomery *et al*. 1963) and feeding (Radloff and Schultz, 1963) of propionate has caused significant reductions in hay consumption by dairy cows.

Certain types of rations are known to cause elevated levels of rumen propionate and corresponding decreases in milk fat. McCullough (1966) summarized 34 feeding trials in which the molar per cent of rumen propionate accounted for 84 per cent of the variation in milk fat. A molar per cent above 20 resulted in consistent decreases in milk fat. Jorgensen and Schultz (1963) found that pelleted rations lowered the rumen acetate:propionate molar ratio and depressed milk fat. Huber and Boman (1966) reported that cows receiving high grain-low forage rations had increased rumen propionate and depressed milk fat. Rumen acetate and butyrate were not affected. Bauman *et al*. (1971) feeding a high-grain, low-fiber ration, demonstrated the characteristic decrease in the acetate:propionate ratio and a corresponding depression in milk fat. A 230 per cent increase in propionate production accounted for the change in the molar ratio of the acids. This is in agreement with Davis (1967) who concluded that reduction in acetate is not the cause of depressed milk fat when high-grain, low-fiber rations are fed to dairy cows.

Lactic Acid and Dairy Cattle Performance

Lactic acid is a product of normal rumen and silage fermentations. Supplemental lactic acid has had small and varied effects in dairy cattle rations. Emery *et al*. (1961) reported that lactic acid addition to corn silage decreased appetite, but increased feed efficiency in proportion to its concentration when fed to growing heifers. Montgomery *et al*. (1963) reported that intraruminal infusion of lactic acid caused a slight decrease in the intake of hay and an increase in the per cent butyric acid in the rumen. Radloff and Schultz (1963) reported that feeding lactate to dairy cows had no effect upon hay consumption, but did increase the solids-not-fat content of the milk. Rumen infusions of lactic acid by Rook *et al*. (1965) increased solids-not-fat and casein and had varying effects upon milk yields and fat content. Rumen concentrations of lactic acid and butyric acid were increased after lactic acid infusions. This supports the work of Montgomery and Baumgardt (1963) which indicated a conversion of lactic to butyric acid when lactic acid was infused into the rumen. Emery _et al_ (1966) reported that supplemental lactic acid did not influence milk production or feed intake for dairy cows, nor did it affect gain or intake for dairy heifers. Rumen lactate tended to be higher for lactate fed cows.

Ammonium Salts in Corn Silage

Formation

Urea or ammonia addition to corn silage results in the formation of ammonium salts of organic acids. Ammonia added to corn silage is more effective in the formation of ammonium salts than equivalent nitrogen as urea because only about 50 per cent of the urea is hydrolyzed to ammonia during fermentation (Huber _et al_., 1968). Beattie and Henderson (1970) found that 58 per cent of the increase in total crude protein of corn silage treated with a suspension of ammonia, minerals, and molasses was in the form of ammonium salts and only a 20 per cent increase resulted from urea treatment of silage. Henderson et al. (1971 a, 1971 b, and 1971 c) and Henderson and Bergen (1972) reported similar increases in ammonium salts for ammonia additions to corn silage.

Lactic acid is the primary organic acid produced in silage fermentation, thus the major ammonium salt found is ammonium lactate. Beattie and Henderson (1970) reported an 81 per cent increase in lactic acid when corn silage was treated with an ammonia suspension. Significant increases in lactic acid of ammonia treated corn silages have also been reported by Henderson et al. (1971 a, 1971 b, and 1971 c), Henderson and Bergen (1972), Huber and Thomas (1971), Huber and Santana (1972), and Huber et al. (1973). The added ammonia apparently buffers the silage and extends the period of microbial fermentation.

Animal Performance

The feeding of ammonia-treated silage has resulted in superior livestock performance. Beattie and Henderson (1970), Henderson et al. (1971 a, 1971 b, and 1971 c) and

Henderson and Bergen (1972) reported average daily gains and feed efficiencies of steers fed corn silages treated with the ammonia suspension were equal or superior to those fed rations supplemented with soybean meal. Huber and Thomas (1971) showed higher milk yields for dairy cows receiving corn silage treated with the ammonia suspension than for those receiving urea-treated silage. Huber and Santana (1972) found milk yields of cows fed ammonia-treated silage were equal to controls fed soybean meal. Huber _et al_. (1973) reported higher milk yields from cows fed ammoniated than urea or control silages.

MATERIALS AND METHODS

Design

Thirty-six lactating dairy cows were assigned to one of four treatment groups in a randomized block design. Milk yields during a 2-week standardization period were used as the blocking factor. Treatment groups were also balanced for age, breeding groups, and days after parturition. The treatments were soybean meal, urea, ammonium propionate, and ammonium lactate.

Production of Ammonium Salts

The ammonium salts were produced by neutralizing propionic or lactic acid with anhydrous ammonia in a 1900 ℓ, stainless steel tank equipped with a sparger system for adding anhydrous ammonia, an agitator, a pH probe, and a water jacket for cooling. Anhydrous ammonia was introduced into the organic acid, water mixture until the pH reached

7.0. The solution was then removed from the tank and stored in 208 ℓ barrels lined with polyethylene.

Samples were analyzed by the micro-Kjeldahl procedure to establish the nitrogen content of the solutions. The composition of the salts is presented in Table 1.

TABLE 1.--Composition of ammonium salts

	Ammonium Propionate	Ammonium Lactate
Ammonia (%)	10.8(8.87)[a]	9.6(7.92)[a]
Acid(%)	54.4	65.1
H_2O(%)	34.8	25.3

[a]Value in parentheses is % nitrogen.

Feeding Trial

Four isonitrogenous concentrates supplying approximately equal amounts of energy, calcium, phosphorus, and vitamins were formulated using soybean meal, urea, ammonium propionate or ammonium lactate as the nitrogen sources. Nonprotein nitrogen supplied 40 per cent of the total crude protein in the urea, ammonium propionate and ammonium lactate concentrates. The ingredient composition of the concentrates is given in Table 2.

At the start of the 84-day treatment period, the cows were fed concentrate at 1 kg per 2.5 kg milk based on standardization production. Concentrate levels were reduced for all cows by 5 per cent at day 35 and by an additional 5 per cent at day 70.

Each cow's concentrate was mixed with sufficient corn silage to yield a 10 per cent refusal of the complete feed. Rations were fed once daily and orts were removed and weighed just prior to feeding. Intakes of concentrate and silage were calculated with the assumption that the proportions of each in the orts were the same as those fed.

Milk weights were recorded from a Surge, Tru-Test milk meter[A] for AM and PM milkings, 5 days per week.

Feed Analysis

Silages were sampled Monday, Wednesday, and Friday during the trial, composited weekly and frozen at -20 C. Concentrate samples were taken from each batch (approximately every 10 days) and refrigerated at 5 C. Upon

[A]Babson Bros. Co., Oak Brook, Illinois.

TABLE 2.--Ingredient composition of concentrates.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Ground shelled corn (%)	44.6	54.0	44.6	44.6
Oats (%)	22.0	26.5	22.0	22.0
Soybean meal (50% C.P.) (%)	16.6	----	3.1	3.1
Urea (%)	----	2.4	----	----
Ammonium Propionate (%)	----	----	13.5	----
Ammonium Lactate (%)	----	----	----	13.5
Beet pulp (%)	10.0	10.0	10.0	10.0
Dehydrated molasses (%)	4.0	4.0	4.0	4.0
Dicalcium phosphate (%)	0.6	1.0	1.1	1.1
Ground limestone (%)	1.2	1.1	1.0	1.0
Trace mineralized salt (%)	1.0	1.0	1.0	1.0
Vitamin A (IU/kg)	4400	4400	4400	4400
Vitamin D (IU/kg)	1100	1100	1100	1100

completion of the trial the concentrates and the silages were further composited into 3 samples of every 4-week period.

Silage dry matters were determined by drying in a forced air oven for 24 hours at 90 - 100 C. Nitrogen analyses were by macro-Kjeldahl. Silage samples were prepared for pH, lactic acid and volatile fatty acids (VFA) by homogenizing 40 g of silage and 160 mℓ of distilled water in a Sorvall Omni-Mixer[A] for 3 minutes with the homogenizer cup immersed in ice. The pH of the homogenized material was measured with a Sargent pH meter.[B] Extracts of the silage were prepared by straining the homogenate through 2 layers of cheesecloth. Fifteen mℓ of the extract was added to 1.5 mℓ of sulfasalicylic acid (SSA) and centrifuged at 15,000 rpm for 10 minutes. The supernatant was removed and frozen for lactic acid and VFA analysis.

Lactic acid determinations were according to the colorimetric procedures of Barker and Summerson (1941). Volatile fatty acids were determined by injecting 3 $\mu\ell$ samples into a Hewlett-Packard, F and M gas chromatograph[C]

[A] Ivan Sorvall, Inc., Newton, Conn.
[B] E. H. Sargent and Co., Chicago, Ill.
[C] Hewlett-Packard, F and M Scientific Co., Model 402.

using a glass column packed with chromasorb 101 (80/100 mesh). The injection port temperature was set at 340 C, the column temperature at 285 C, and the flame detector at 320 C. Nitrogen was used as the carrier gas and flow rate was 30 - 40 mℓ per minute. Sample VFA concentrations were calculated by comparing peak heights with those of analytical grade acids in a stock solution. The average chemical analysis of the corn silage fed is shown in Table 3.

TABLE 3.--Chemical analysis of corn silage.

Item	Value
Dry Matter (%)	31.53
Crude Protein (% of DM)	9.10
Acetic Acid (% of DM)	2.91
Propionic Acid (% of DM)	0.20
Butyric Acid (% of DM)	0.08
Lactic Acid (% of DM)	10.76
pH	3.65

Concentrates were analyzed for dry matter and nitrogen as previously described for silage. The average dry matter and crude protein of the concentrates fed are presented in Table 4.

TABLE 4.--Chemical analysis of concentrates.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Dry Matter (%)	88.9	89.4	84.6	85.8
Crude Protein (% of D.M.)	18.6	18.3	19.2	18.4

Milk Analysis

Composite (AM and PM) samples of milk were taken from each cow at biweekly intervals during the feeding trial and twice during standardization with a Surge, Tru-Test milk meter. Total solids were determined by drying 2 mℓ for 2 hours in a forced air oven at 90 - 100 C. Butterfat was determined by the Babcock method. A portion of each sample was frozen at -20 C and at the end of the trial analyzed for nitrogen by the micro-Kjeldahl procedure.

Rumen Fluid Analysis

At the end of the feeding trial (day 85), rumen field was sampled by stomach tube from all cows at 2 and 5 hours post-feeding. Feed was not removed during sampling.

The rumen fluid was strained through 2 layers of cheesecloth and the pH was measured with a Beckman pH meter.[A] A sample was prepared for ammonia analysis by adding 1 mℓ of mercuric chloride (saturated) to 19 mℓ of the strained rumen fluid. To a second 5 mℓ sample, 1 mℓ of metaphosphoric acid was added; and after centrifuging at 10,000 rpm for 10 minutes, the supernatant was frozen for volatile fatty acid (VFA) and lactic acid determinations.

Rumen ammonia was determined by the micro-diffusion method of Conway (1963). VFA and lactic acid determinations were as previously described.

[A]Beckman Industries, Inc., South Pasadena, Calif., Model G.

Statistical Analysis

All data were analyzed on a Control Data Corporation 3600 computer located at the Michigan State University Computer Laboratory. Analysis of variance and analysis of covariance programs were used and where statistical significance was revealed, differences between treatment means were tested by orthogonal comparisons.

RESULTS AND DISCUSSION

Feed Intake

Average daily intakes of concentrate and silage dry matter are shown in Table 5. Intakes were not significantly different; however, cows receiving ammonium propionate and ammonium lactate consumed slightly less corn silage and concentrate. Total dry matter intakes averaged 18.4, 18.7, 17.7, and 17.9 kg per day, respectively, for the groups fed soybean meal, urea, ammonium propionate, and ammonium lactate.

TABLE 5.--Dry matter intakes of cows fed various nitrogen supplements.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Corn silage (kg/day)	10.9	10.9	10.4	10.5
Concentrate (kg/day)	7.5	7.8	7.3	7.3
Total (kg/day)	18.4	18.7	17.7	17.9

Lower intakes for steers fed ammonium propionate have been reported by Allen (1972 a). Intake depression has been shown with propionate infusion or feeding (Montgomery *et al.*, 1963; Radloff and Schultz, 1963; and Bristol *et al.*, 1972), and with lactate feeding (Emery *et al.*, 1961 and Montgomery *et al.*, 1963).

Urea did not depress intakes as reported by others for concentrates with more than 2 per cent urea (Van Horn *et al.*, 1967 and Huber *et al.*, 1968). Mixing the concentrate with the silage distributed the urea throughout the total ration and may have better masked its taste. Huber and Cook (1972) determined that depressed intakes with the feeding of urea were a result of its objectionable taste. Our method of feeding may also have helped to maintain intakes of the ammonium salts.

Daily intakes of crude protein and crude protein as a per cent of dry matter were similar for all groups (Table 6). Nonprotein nitrogen (NPN) supplied about 25 per cent of the total crude protein in the urea and ammonium salt rations. Average consumption of urea, ammonium propionate and ammonium lactate were 209, 1170, and 1151 g per day, respectively.

TABLE 6.--Protein intakes of cows fed various nitrogen supplements.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Total CP (kg/day)	2.39	2.42	2.35	2.31
Total CP (% of DM)	13.0	12.9	13.3	12.9
NPN (% of total CP)	-----	24.3	27.3	24.9
Urea or NH_4 salt (g/day)	-----	209	1170	1151

Milk Yields

Yields of milk and fat corrected milk (FCM) are shown in Table 7. Average milk yields were not significantly different, but were highest for the ammonium propionate group (24.0 kg) and lower on ammonium lactate (22.2 kg). Persistencies of production and treatment means adjusted by covariance for standardization were also highest for ammonium propionate and lower on ammonium lactate, but not significant.

Adjusted means of FCM were 19.9, 21.1, 22.7, and 20.9 kg per day for the soybean meal, urea, ammonium

TABLE 7.--Milk yields of cows fed various nitrogen supplements.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Standardization (kg/day)	24.8	26.0	25.4	24.4
Treatment (kg/day)	23.1	23.7	24.0	22.2
(Std. ÷ treat) x 100	92.9	92.8	96.1	91.3
Adj. treat (kg/day)[a]	23.3	23.0	23.8	22.7
FCM (kg/day)	19.6	22.6	21.8	20.6
Adj. FCM (kg/day)[ab]	19.9	21.1	22.7	20.9

[a]Adjusted by covariance for standardization.

[b]SBM < NPN treatments ($P < .05$).

propionate and ammonium lactate treatments, respectively. Means for the nonprotein nitrogen (NPN) groups were higher ($P < .05$) than for soybean meal.

Figure 1 shows the regression lines obtained when treatment milk yields were regressed on standardization yields to determine the influence of level of production upon the treatment response. The slopes (b) of the lines were .99, .64, .67, and .78 for the respective treatments. These slopes were not significantly different, but suggest

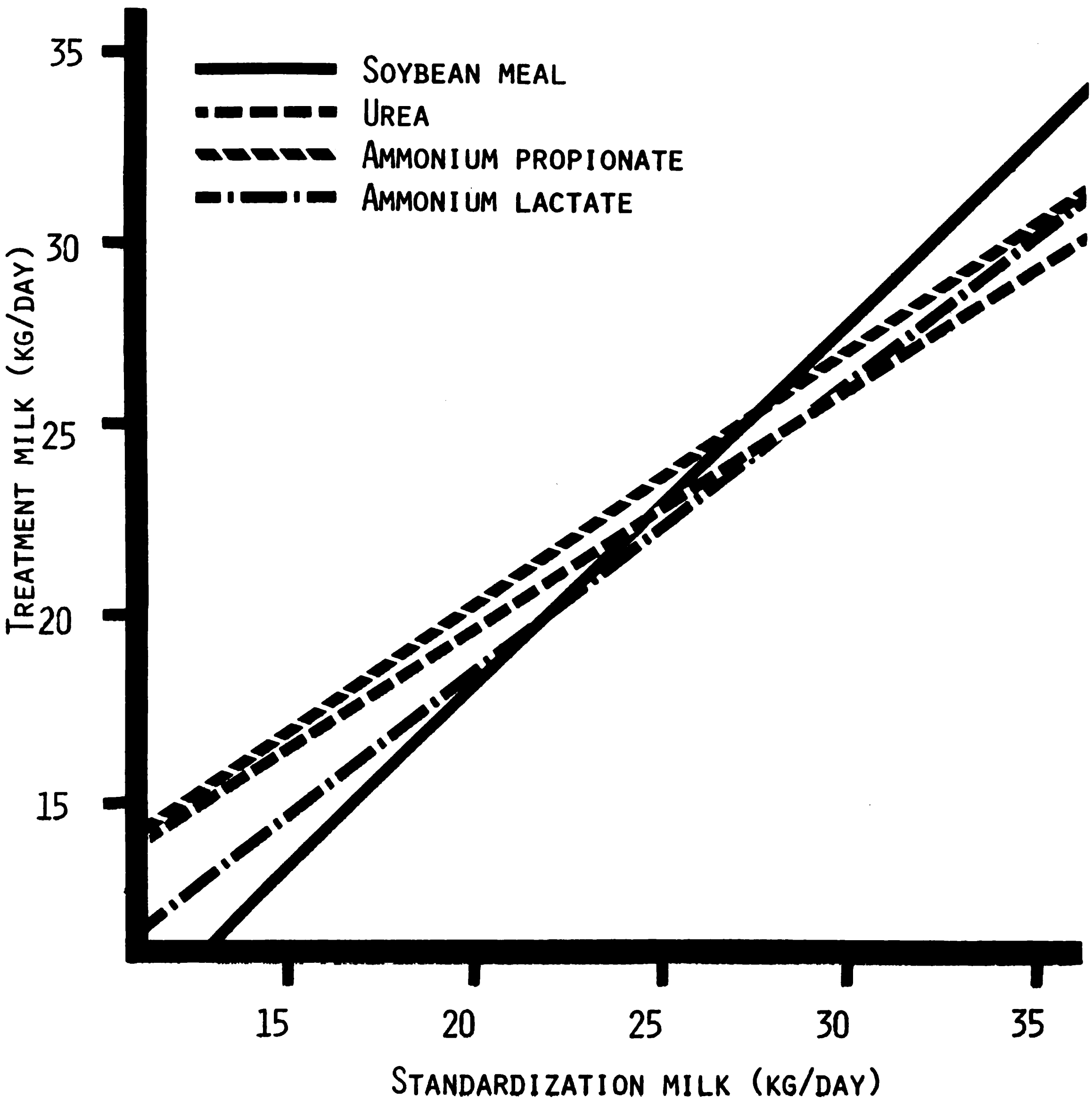

Fig. 1.--The influence of standardization milk yields on treatment response.

that the response to NPN supplements was less favorable for the higher than for the lower producing cows. The response to soybean meal did not appear to be affected by level of production. A similar pattern of differential responses to varying urea intakes has been reported by Huber et al. (1972). Cows producing over 25 kg milk per day had lower persistencies than cows under 25 kg when urea intakes exceeded 180 g per day.

Milk Composition

Milk total solids, fat, solids-not-fat, and protein are shown in Table 8. Adjusted means for per cent total solids were 11.82, 12.42, 12.63, and 12.36 for the respective treatments, with the NPN groups higher ($P < .01$) than the soybean meal.

Most of the difference in total solids was due to the fat content. Adjusted treatment means for per cent fat were 3.00, 3.58, 3.52, and 3.52 for the respective treatments. Again NPN groups were higher ($P < .01$) than the soybean meal group.

TABLE 8.--Milk composition of cows fed various nitrogen supplements

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
<u>Total Solids</u>				
Standardization (%)	12.22	13.01	12.20	12.68
Treatment (%)	11.63	12.72	12.43	12.46
Adj. treat. (%)[ab]	11.82	12.42	12.63	12.36
<u>Fat</u>				
Standardization (%)	3.83	4.30	3.56	3.98
Treatment (%)	2.98	3.71	3.41	3.54
Adj. treat. (%)[ab]	3.00	3.58	3.52	3.52
<u>Solids-not-fat</u>				
Standardization (%)	8.39	8.71	8.64	8.70
Treatment (%)	8.65	9.01	9.02	8.92
Adj. treat. (%)[a]	8.84	8.92	8.99	8.83
<u>Protein</u>				
Standardization (%)	3.01	3.21	3.09	3.21
Treatment (%)	3.19	3.33	3.29	3.30
Adj. treat. (%)[a]	3.26	3.28	3.31	3.25

[a]Adjusted by covariance for standardization.

[b]SBM<NPN treatments ($P < .01$).

By comparing standardization means with treatment means, it is noted that all rations resulted in some depression of per cent fat. The greatest depression occurred on soybean meal (-.85) and the least on ammonium propionate (-.15). These are contrary to results obtained when propionate was fed or infused without the accompanying ammonium radical (Rook and Balch, 1961; Rook et al., 1965; Fisher and Elliot, 1966; and McCullough et al., 1969). However, Jones (1971) was able to maintain fat test when feeding concentrates containing 1 per cent urea and varying levels of propionate. The lower fat depression ($P < .05$) on the NPN rations suggests that the ammonia buffered the products of rumen fermentation which would have otherwise decreased fat in milk.

Treatment differences in solids-not-fat (SNF) were not significant; however, the adjusted mean for the ammonium propionate group was highest. Increases in SNF have been reported by Rook and Balch (1961), Rook et al. (1965), and McCullough et al. (1969) when propionate was infused or fed.

Adjusted means for per cent protein in the milk were 3.26, 3.28, 3.31, and 3.25 for the respective treatments. Differences were not significant, but the higher propionate value is in agreement with the results of Rook and Balch (1961) and Rook et al. (1965) who noted increases in milk protein when propionate was intraruminally infused.

Rumen Fluid Composition

Since the cows were allowed to eat during the sampling period, rumen fluid samples taken at 2 and 5 hours post-feeding did not show changes in composition over time. All rumen fluid data in this section are averages of the 2 and 5 hour samples. Values for individual samplings are reported in appendix Tables 1 and 2. Rumen ammonia, pH, and lactic acid are shown in Table 9.

Ammonia

Average rumen ammonia concentrations for the respective groups were 7.21, 11.56, 11.62, and 14.14 mg per 100 mℓ. The nonprotein nitrogen (NPN) treatments were higher ($P < .05$) than soybean meal. Varner and Woods

TABLE 9.--Rumen ammonia, pH, and lactic acid of cows fed various nitrogen supplements.[a]

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Ammonia (mg/100 mℓ)[b]	7.21	11.56	11.62	14.14
pH[c]	6.74	7.06	6.86	7.08
Lactic acid (mg/100 mℓ)	8.46	4.58	7.32	14.86

[a]Average of samples taken at 2 and 5 hours post-feeding.

[b]SBM $<$ NPN treatments ($P < .05$).

[c]SBM $<$ NPN treatments ($P < .01$).

(1968 and 1971) reported similar results in work with steers.

The highest rumen ammonia was noted for the ammonium lactate group. These data agree with Allen et al. (1972 b) who reported that steers fed ammonium lactate or ammonium acetate had higher rumen ammonia than those on other NPN supplements or soybean meal. Allen (1972) subsequently reported higher rumen ammonia levels for steers fed urea than soybean meal or ammonium salts.

PH

Average rumen pH values were 6.74, 7.06, 6.86, and 7.08 for the respective treatments. Groups fed NPN were higher ($P < .01$) than those fed soybean meal which agrees with Allen (1972 b), but is in contrast to the findings of Varner and Woods (1969 and 1971) who reported that pH was lower for steers fed ammonium salts than for those fed urea or soybean meal.

Lactic Acid

Average levels of rumen lactic acid for the respective groups were 8.46, 4.58, 7.32, and 14.86 mg per mℓ. Large variations within treatments prevented differences from being significant; however, the highest mean was shown for the group fed ammonium lactate. Rumen lactic acid concentrations have not been reported by other workers when ammonium lactate was fed. The highest lactic acid detected was 91.2 mg per 100 mℓ, a level much less than those associated with lactic acidosis (Uhart and Carroll, 1967).

Volatile Fatty Acids

Rumen volatile fatty acid (VFA) concentrations and acetate:propionate ratios are shown in Table 10. The value given for total VFA is a sum of the acetate, propionate, and butyrate concentrations.

TABLE 10.--Rumen volatile fatty acid concentrations for cows fed various nitrogen supplements.[a]

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Total VFA (mMoles/100 mℓ)	6.7	5.9	6.9	6.2
Acetate (mMoles/100 mℓ)	4.3	3.8	4.0	3.8
Propionate (mMoles/100 mℓ)[b]	1.3	1.2	2.0	1.4
Butyrate (mMoles/100 mℓ)	1.1	0.9	0.9	1.0
Acetate/Propionate[b]	3.26	3.16	2.15	2.87

[a]Average of samples taken at 2 and 5 hours post-feeding.

[b]Ammonium propionate different from other treatments ($P < .01$).

Total VFA's were 6.7, 5.9, 6.9, and 6.2 mMoles per 100 mℓ for the soybean meal, urea, ammonium propionate, and ammonium lactate groups, respectively. Values were not significantly different. Varner and Woods (1968 and 1971) reported total VFA's were higher for steers fed ammonium salts than urea or soybean meal.

The concentration of propionate in the rumen was higher ($P < .01$) for cows fed ammonium propionate than for other treatments. Varner and Woods (1971) and Allen _et al_. (1972 b) have reported that the molar concentration of a particular VFA increases with the feeding of that acid as an ammonium salt. Concentrations of acetate or butyrate were not affected by treatment.

The rumen acetate:propionate ratio was lower ($P < .01$) for ammonium propionate than for other treatments.

Molar per cents of rumen acetate, propionate and butyrate are shown in Table 11. The ammonium propionate ration increased ($P < .01$) the molar per cents of propionate and decreased ($P < .01$) the molar per cents of both acetate and propionate.

The rumen changes which occurred with the feeding of ammonium propionate have previously been associated with

TABLE 11.--Proportions of volatile fatty acids in rumen fluid of cows fed various nitrogen supplements.[a]

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Acetate (Molar %)[b]	63.7	64.3	58.3	62.2
Propionate (Molar %)[b]	20.1	21.0	28.5	22.1
Butyrate (Molar %)[b]	16.2	14.6	13.2	15.7

[a]Average of samples taken at 2 and 5 hours post-feeding.

[b]Ammonium propionate different from other treatments ($P < .01$).

a depression in milk fat (McCullough, 1966; Davis, 1967; and Bauman et al., 1971). In this study, high rumen propionate and low acetate:propionate ratio did not depress milk fat. This suggests that the ammonium radical of the ammonium propionate buffered the rumen contents sufficiently to prevent a depression in milk fat.

Significance of Results

This study indicates that ammonium propionate or ammonium lactate can successfully supply supplemental nitrogen for lactating dairy cows. At present, ammonia is an economical source of nitrogen, thus the ammoniation of organic acids merits further investigation. Of particular interest are those acids formed as products of fermentations. Certain by-products which are presently considered to be waste and contribute to the pollution of our environment, may, after fermentation, be potential carriers of ammonia in dairy rations.

Several organic acids are presently being studied as preservatives for forages and grains. Should the ammonium salts of these acids prove to be effective preservatives, they could serve an additional purpose by increasing the crude protein of the treated feedstuff.

Regardless of the form of nonprotein nitrogen added to the ration, it is important that an optimum level be determined which will maximize profit for the dairyman.

SUMMARY

The value of ammonium propionate and ammonium lactate as supplemental nitrogen sources was assessed in a feeding trial with lactating dairy cows. Milk yields, milk composition, and rumen parameters were measured.

Soybean meal and urea supplemented rations served as natural protein and nonprotein nitrogen (NPN) controls, respectively. Concentrates containing the nitrogen supplements were mixed with corn silage and fed as a complete feed, once daily.

Cows consumed slightly less of the ammonium propionate and ammonium lactate rations. Milk yields and persistencies were highest for the ammonium propionate group, but not significantly different from other groups. Yields of fat-corrected-milk, adjusted for standardization were higher ($P < .05$) for NPN supplemented groups than for those receiving soybean meal.

Treatment response as measured by regression of treatment milk on standardization milk showed that the

higher producing cows performed best on soybean meal, but the lower producers performed better on NPN supplements.

Per cent total solids and fat of the milk, adjusted for standardization, were higher ($P < .01$) for groups fed the NPN rations than for soybean meal. Per cent solids-not-fat and protein were highest for ammonium propionate, but not significantly different from other treatments.

Rumen ammonia and pH were higher ($P < .05$) for NPN than for the soybean meal groups. Lactic acid was highest on ammonium lactate, but not significantly different across treatments. Total rumen volatile fatty acids (VFA) were not different, but rumen propionate was highest ($P < .01$) and acetate:propionate ratio lowest ($P < .01$) for cows fed ammonium propionate.

Ammonium propionate and ammonium lactate proved satisfactory sources of supplemental nitrogen for lactating dairy cows compared to urea or soybean meal. Furthermore, the NPN rations maintained a higher per cent milk fat than did soybean meal rations.

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APPENDIX

APPENDIX TABLE 1.--Rumen ammonia, pH, and lactic acid of cows fed various nitrogen supplements

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Ammonia (mg/100 mℓ)				
2 hours	9.90	16.11	15.64	20.87
5 hours	4.79	10.43	9.61	8.29
pH				
2 hours	6.84	6.99	6.83	7.07
5 hours	6.64	7.12	6.88	7.10
Lactic acid (mg/100 mℓ)				
2 hours	14.56	2.67	10.58	23.43
5 hours	2.37	6.31	4.07	6.28

APPENDIX TABLE 2.--Rumen volatile fatty acids of cows fed various nitrogen supplements.

	Soybean Meal	Urea	Ammonium Propionate	Ammonium Lactate
Total VFA (mMoles/100 mℓ)				
2 hours	7.8	6.2	7.7	6.4
5 hours	5.6	5.5	6.1	5.9
Acetate (mMoles/100 mℓ)				
2 hours	5.0	3.9	4.4	3.9
5 hours	3.6	3.6	3.6	3.8
Propionate (mMoles/100 mℓ)				
2 hours	1.6	1.3	2.3	1.5
5 hours	1.1	1.1	1.7	1.2
Butyrate (mMoles/100 mℓ)				
2 hours	1.3	0.9	1.0	1.0
5 hours	0.9	0.8	0.8	0.9
Acetate/Propionate				
2 hours	3.11	3.00	1.98	2.65
5 hours	3.40	3.25	2.31	3.09