THE EFFICIENCY OF UTILIZATION OF THE EXOGENOUS AMMONIUM SALTS OF VOLATILE FATTY ACIDS AND HEMICELLULOSE EXTRACT IN RUMINANTS

by

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TABLE OF CONTENTS

INTRODUCTION

The expanding world population has brought new challenges to nutritionists. It is becoming more difficult to justify using large quantities of cereal grains to feed the ruminant animal, while the human demand for direct consumption of these grains increases.

The unique ability of a ruminant animal to utilize cellulose and other substances unfit for human consumption has already made the ruminant a valuable animal.

The necessity of finding new sources of energy for the ruminant animal has led to consideration of utilizing industrial byproducts as animal feeds. Many byproducts which have no nutritional value for humans might prove useful in producing animal products. Two such industrial byproducts are volatile fatty acids and hemicellulose extract. Ammonium salts of the volatile fatty acids could prove to be a useful source of energy and nitrogen for the animal. Hemicellulose extract, a byproduct of the wood industry, might be utilized as a carrier or protector of nonprotein nitrogen compounds such as urea.

PART I. FEEDING AND UTILIZATION OF AMMONIUM SALTS OF VOLATILE FATTY ACIDS

REVIEW OF LITERATURE

Acetic and propionic acids, products of rumen fermentation, have been shown to furnish most of the energy needed by the ruminant animal. Because of the increasing demand for cereal grains for human consumption, and because of the ability of ruminants to utilize volatile fatty acids (VFA) and nonprotein nitrogen, supplying exogenous energy and nitrogen as ammonium salts of acetic and propionic acids may prove to be an economical method of meeting the energy and protein needs of these animals.

VFA and Energy Utilization

Holter et al. (1970) intraruminally infused individual VFA or a mixture of VFA into fasting cows and found heat increments to be 40 kcal per 100 kcal metabolizable energy for acetate, 18 kcal per 100 kcal for propionate, and 18 kcal per 100 kcal for butyrate. The heat increment of the mixture was 32 kcal. This is similar to the heat increments of 41% for acetic, 13% for propionic, 16% for butyric, and 15% for a mixture of VFA found by Armstrong et al. (1957). Armstrong et al. (1958) found that a mixture of VFA with 75% acetic acid produced a heat increment of 42%. A depression of methane occurred when 900 kcal mixtures of VFA were infused into the rumen, the depression increasing with increased acetic acid infusion.

Poole and Allen (1970) found that acetic acid was utilized more efficiently than propionic acid on a high concentrate diet but was utilized less efficiently than other acids on a low concentrate diet. It was suggested that acetic acid concentration became sufficiently high to cause wasteful oxidation.

Blaxter (1962) reported the calorimetric efficiency of acetic acid as 59.2%, propionic as 86.5%, butyric as 76.4%, a mixture of propionic and butyric as 90.7% and a mixture of all three as 85.6%. Severe metabolic disturbances were reported when acetic acid was used as the sole source of energy over a period of time.

Bull et al. (1970) concluded that a lag in the pentose-phosphate shunt activity resulting from a deficiency of glucose could lead to increased oxidation of acetic acid, with a resulting high heat increment. When acetate and glucose were infused together into the rumen of sheep, the flow of glucose through the pentose shunt increased by 60% over that of glucose infusion alone. The metabolizable net efficiency of acetic acid utilized for body energy gain was found to be 76.4%, close to the theoretical net efficiency of 77.7%.

VFA for Growth

Essig et al. (1962) found that both salts of VFA and free VFA reduced feed intake and average daily gain with the free VFA having the greatest effect. Essig et al. (1959) found that a mixture of soy protein, starch, and glucose fed with the VFA resulted in similar or better gains than when cattle were fed rations with ground corn cobs as the major energy source.

Staubus et al. (1958) reported that calves fed 50 g of sodium acetate in milk and free choice calf starter had a marked improvement in rate of growth and feed efficiency over calves on the same ration without acetate. The acetate-fed calves gained .86 kg per day with a feed efficiency of 1.47 kg dry matter per kg gain compared to .6 kg per day gain and a feed efficiency of 1.6 kg dry matter per kg gain for the control ration. Matrone et al. (1959) fed lambs 2 yr on a purified diet supplemented with 32% VFA salts. The weight gains and health of the lambs were good. Orskov and Allen (1966) found that lambs receiving rations containing 12% VFA salts grew faster and had significantly greater empty body weights and carcass weights than those receiving unsupplemented rations. There were no differences in efficiency with which acetate, propionate, or butyrate promoted weight gains. Poole and Allen (1970) supplemented high concentrate and low concentrate rations with different levels of sodium or calcium acetate. The acetate supplemented lambs made greater live weight, empty weight, and carcass weight gains than did the controls. The gains from acetate were greatest on the high concentrate rations.

Holstein heifers fed propionic acid treated high moisture corn gained .6 kg per day versus .5 kg per day for controls (Jones et al., 1970). The heifers consumed .91 kg more dry matter per day on the treated corn than on the untreated corn. Rook et al. (1963) found an increase in nitrogen retention and body weight gains with intraruminal infusions of VFA in sheep.

VFA and Voluntary Intake

Acetic and propionic acids have been found to depress appetite. Montgomery et al. (1963) found a significant reduction in hay consumption when acetic acid (870 g) was infused into the rumen. Infusion of the acid as a sodium salt, or after neutralization to pH 5 with sodium hydroxide, resulted in only a slight reduction in hay intake. Wyatt (1965) studied the influence of the plane of nutrition on the effects of VFA on appetite. Intraruminal infusions of .4 kcal of acetic acid reduced intake of feed. Infusion of .4 kcal of propionic acid increased feed intake. Animals on a low energy diet showed a more severe reduction of intake with infusion of VFA than those on a high energy diet. It was concluded that the depression in intake was not the result of a simple substitution of feed calories by acid calories, but instead, the result of a chemostatic control of appetite. Baile and Meyer (1968) depressed feed intake in goats by intraruminal infusions of sodium acetate, but found no effect with intravenous infusion of acetate. It was suggested that receptors sensitive to acetate are in the lumen of the rumino-reticulum.

In conflict with the hypothesis that VFA reduce appetite through satiety or fill, Dinius et al. (1968) stated that reduced feed intake is due to energy demands being met by the VFA. This was supported by the results of a trial in which corn silage was supplemented with sodium acetate at levels of 1 to 6% of the ration. Although the dry matter intake significantly decreased with addition of 6% acetate, there was no significant change in caloric intake.

Repp et al. (1955) obtained very similar results between ammonium acetate (5% of diet) and urea (2.2% of diet) on feed intake. Lambs did not accept the rations at first but after 2 wk became accustomed to them.

McCollough et al. (1969) found no reduction in total feed intake of dairy cows when sodium salts of VFA, added to a complete silage ration, were given in frequent feedings in small amounts.

Senel and Owen (1967) found no reduction in dry matter intake with the addition of 2% acetic, 1% butyric or a mixture of the two to hay. A mixture of 4% acetic and 2% butyric acids added to hay was found to significantly reduce intake. The pungent odors were thought to discourage consumption of the hay. Martin et al. (1959) reported that the gross energy intake for a ration with 32% mixed VFA was similar to the intake of a control ration. The VFA produced no ill effects. Thomas et al. (1961) infused VFA or mixtures of VFA into the rumens of silage fed heifers. No decrease in intake occurred with infusion of a mixture of 228 g lactic, 126 g acetic, and 10 g butyric acids, neutralized to a pH of 5. Individual infusions of 288 g lactic, 126 g acetic, or 100 g of propionic acids did not affect intake; however, a mixture of the three depressed silage intake by 0.56 kg per heifer per day. An infusion of 576 g lactic and 252 g acetic acids reduced silage intake by 1.36 kg per heifer per day. The decreases in intake were not as severe when the acids were fed with the silage as when infused.

Bartley et al. (1973) added 146 kcal of sodium or ammonium acetate or propionate to the rations of dairy cows and found that feed intake was reduced 17%. The addition of 3.9% acetate to silage did not reduce intake.

Webb (1971) added from 5% to 8% ammonium acetate to the drinking water of lactating cows and found a reduction of liquid intake in almost every case. Kay et al. (1967) reported reductions of 12 to 15% in liquid intake when 1% acetate was added to the drinking water. Prescott et al. (1969) found no depression of liquid intake with addition of 1.4% VFA salts; however, a concentration of 2.6% acetate added to the water depressed liquid intake.

Webb (1971) added 20% ammonium salts to a molasses liquid supplement. The cows consumed an average of 540 g of acetate per cow per day with no reduction in feed intake.

Ammonium VFA Salts for Growth

Cattle fed a mixture of ammonium VFA salts in a 30:40:30 ratio (acetate, propionate, butyrate) gained more than cattle fed a urea containing ration and gained the same as cattle fed a soybean meal containing ration (Varner et al., 1968). The best nitrogen retention occurred on the soybean meal containing ration followed by the VFA and urea containing rations.

Varner et al. (1968) compared a ration supplemented with a mixture of 75:15:10 (acetate, propionate, butyrate) ammonium VFA salts with the above ration and found that the low acetate ration gave the best gains.

There were no differences in dry matter, cellulose, or protein digestibility among rations containing ammonium VFA salts, urea, or soybean meal. The nitrogen retention (11.42 g per day) for the high acetate ration was significantly lower than that for the high propionate ration (14.3 g per day).

Repp et al. (1955) reported that lambs did not at first readily accept a ration containing 8.23% ammonium propionate or 5% ammonium acetate because of the odor of ammonia. After becoming accustomed to the rations containing VFA salts, the feed intake and weight gains of the lambs were similar to that of lambs fed rations containing urea.

Santana and Huber (1970) fed dairy cattle corn silage which had been treated with 28% anhydrous ammonia. These cattle gained more than cattle fed untreated silage.

Belasco and Bessman (1955) added ammonium acetate which was equivalent to 187 mg of nitrogen to a continuous in vitro fermentation system and obtained 95 mg of ammonia after 24 h. The ammonia nitrogen utilization and cellulose digestion of the acetate substrate were 95% and 97% of the urea response, respectively. Bacterial growth was excellent.

Toxicity of Ammonium VFA Salts

Repp et al. (1955) found that urea and ammonium salts of acetic, propionic, and formic acids were nearly equal in producing toxicity when they were administered on an isonitrogenous basis to lambs. Ammonium propionate was slightly more toxic than the others. The toxic level of the treatments was about 40 g of urea equivalent per 100 lb body weight. It was found that no toxicity resulted when

acetic acid was administered as a drench simultaneously with the treatments. Oral administration of acetic acid after the onset of toxicity helped to relieve toxicity.

Webb (1971) found that toxicity in cattle was produced from smaller nitrogen equivalent doses of urea than from ammonium acetate.

VFA Supplementation and Rumen VFA

Supplementing a ration with VFA usually will increase the concentration of the particular acid given, and also increase the total VFA concentration (Rook et al., 1963; McCollough, 1970). Kay et al. (1969) observed that the feeding of an all concentrate ration to calves increased the concentration of propionic acid in the rumen. However, the proportion of propionic acid decreased when sodium acetate was added to the feed. Varner et al. (1968) found that the total concentration of VFA in the rumen was higher when cattle were fed ammonium salts of VFA than when fed urea or soybean meal rations.

Several researchers have found that ingestion of a certain VFA can affect the concentrations of VFA resulting from rumen fermentation. Often, the administration of acetate will result in an increase in butyrate concentrations (Bondarenko and Slesarov, 1965; Senel and Owen, 1967). Van Soest and Allen (1959) reported that reduction in molar percentages of acetic acid in the rumen is actually the result of increases in the propionic acid fraction. Poole and Allen (1970) reported that a high energy ration supplemented with acetate produced low ruminal acetic acid concentrations and high propionic and butyric

acid concentrations. A similar ration with a low energy level produced high ruminal acetic acid percentages and lower percentages of propionic and butyric acids.

Sheep fed at a continuous rate and infused intraruminally with VFA had a production rate of 3.7 moles of acetic acid, 1 mole of propionic acid, and .7 mole of butyric acid per day. Production of the VFA accounted for 80% of the animals' energy expenditure (Bergman et al., 1965).

Effect of VFA on Rumen pH

The change in rumen pH from supplementation of VFA depends on the amount and form of the acid added. Armstrong and Blaxter (1957) infused acetic acid into the rumen of sheep and obtained a pH of 4.6. Rook et al. (1963) found a decrease in pH after intraruminal infusions in heifers of amounts of acetic acid supplying 3500 or 5500 kcal per day. Webb (1971) added urea or ammonium acetate to the rumen and found little or no change in the rumen pH.

EXPERIMENTAL PROCEDURE

This study was designed to determine the effects of ammonium acetate and ammonium propionate added to a low protein ration on nutrient digestibility, nitrogen balance, and voluntary intake. Six steer calves weighing approximately 140 kg were used in a 3x3 Latin square design (Table 1) to test three rations: a) low protein control; b) control plus ammonium acetate (Amace); c) control plus ammonium propionate (Ampro).

Table 1. Experimental design.

	Group 1[a]	Group 2[b]	Group 3[c]
Period 1	Basal	Amace	Ampro
Period 2	Ampro	Basal	Amace
Period 3	Amace	Ampro	Basal

[a] Group 1 Steers 99,100.
[b] Group 2 Steers 103,107.
[c] Group 3 Steers 102,109.

The control ration contained approximately 60% ground corn and 30% prairie hay. A small amount of molasses (4.7%) was added to control dust and enhance palatability. For Amace or Ampro, enough ammonium acetate or ammonium propionate was added to meet the requirements (NRC, 1970) for protein for young steers (Table 2).

A proximate analysis of the rations showed the average crude protein content on an as fed basis to be: control, 7.15%, control plus acetate, 10.24%; control plus propionate, 9.78%.

All steers were fed the control ration for 1 wk during an adjustment period. They were then assigned to three balanced groups and fed the experimental rations.

The duration of each trial period was 4 wk. During the first 2 wk the calves were fed ad libitum twice daily in a stanchion barn to establish maximum intake. During the last 2 wk of the period, the calves were placed in metabolism crates in a climate controlled room where temperature, air flow, and humidity were kept constant. One wk

Table 2. Ration composition (as fed basis).

Ingredient	Basal A %	Amace B %	Ampro C %
	VFA Trial		
Corn	64.3	58.7	59.5
Prairie hay	30.0	29.6	30.0
Molasses	4.7	4.64	4.7
Limestone	.55	.54	.55
Salt	.35	.35	.35
Dical	.1	.1	.1
Vitamin A	10,000 IU/g	10,000 IU/g	10,000 IU/g
Acetate	--	6.07	--
Propionate	--	--	4.8
	Proximate Analysis		
Gross energy (kcal/g)	4.11	4.08	4.10
Crude fiber %	11.17	11.10	10.45
Ether extract %	2.98	2.95	2.73
Dry matter %	90.01	88.35	88.44
Crude protein %	7.15	10.24	9.78
Ash %	4.63	4.45	4.62

was used to allow adjustment to the crates. After intake had stabilized again, the feed was given slightly below maximum intake to insure complete consumption.

During the last 6 days of the period, all feed, feces, and urine was weighted and aliquots taken daily for analysis. Feed and feces were dried for 48 h at 100 C in a forced air oven. They were then ground and proximate components determined by AOAC methods (AOAC, 1970). The energy content of feed and feces was determined by bomb calorimetry, and nitrogen content of the urine was analyzed by the Kjeldahl method (AOAC, 1970).

At the end of each period, the rations were changed and the steers were returned to the stanchion barn. The procedure was then repeated for periods two and three. However, during periods two and three, the calves were given only two days to adjust to the crates because they were more familiar with them than initially. Also, less time in the crates helped to reduce stiffness of feet and legs due to lack of exercise.

RESULTS AND DISCUSSION

The effects of supplementing a low protein ration with ammonium acetate or ammonium propionate on intake are shown in Table 3.

Intake of the rations was approximately the same. No decrease in intake was noted as a result of VFA supplementation. The average daily gain was slightly greater for calves fed the ammonium salts

than for those fed the control ration. However, weight gain data for a small group of steers in metabolism crates are of questionable value.

Table 3. Effect of supplementation of a basal ration with Amace or Ampro on feed intake and body weight gain.

Treatment	Animal number	Avg. daily feed intake (kg)	Avg. daily gain (kg)
Basal	99	4.16	.46
	100	3.44	.29
	102	5.30	.82
	103	4.62	.29
	107	4.44	.43
	109	5.12	.5
	Avg.	4.51 a	.47 a
Amace	99	4.45	.68
	100	5.63	1.07
	102	4.84	.39
	103	4.07	.21
	107	3.84	.32
	109	4.80	.71
	Avg.	4.61 a	.56 a
Ampro	99	4.25	.11
	100	4.65	.71
	102	4.37	.39
	103	6.04	1.2
	107	4.43	.77
	109	3.86	.36
	Avg.	4.60 a	.59 a

[a] None of the differences within columns was statistically significantly different.

The nitrogen intake for cattle fed ammonium salts was greater since those rations contained more nitrogen than did the control ration (Table 4). The amount of nitrogen retained was significantly greater for the supplemented rations. This, and a significant increase

Table 4. Effect of supplementation of a basal ration with Amace or Ampro on nitrogen balance.

Treatment	Animal number	Nitrogen intake[1]	Fecal nitrogen[1]	Urinary nitrogen[1]	Retained nitrogen[1]	Retained % of intake	Retained % of absorbed
		(g)	(g)	(g)	(g)		
Basal	99	276.0	157.6	37.5	80.9	29.3	68.3
	100	277.3	139.8	42.6	94.9	34.2	69.0
	102	383.1	193.0	96.2	93.8	24.5	49.4
	103	351.3	181.2	62.3	107.7	30.7	63.4
	107	319.3	155.2	48.1	116.1	36.4	70.7
	109	326.3	148.3	57.4	120.6	37.0	67.7
	Avg.	322.21	162.51	57.35	102.33 a	32.01 a	64.75 a
Amace	99	449.8	217.4	104.3	128.0	28.5	55.1
	100	523.7	199.5	168.3	155.9	29.8	48.1
	102	516.6	190.3	93.4	232.9	45.1	71.4
	103	407.0	157.6	78.5	170.9	42.0	68.5
	107	407.0	171.3	110.4	125.3	30.8	53.2
	109	475.6	132.1	114.3	229.2	48.2	66.7
	Avg.	463.28	178.03	111.53	173.7 b	37.4 ab	60.5 a
Ampro	99	492.7	150.2	58.4	284.1	57.7	82.9
	100	492.7	172.7	110.7	209.3	42.5	65.4
	102	463.8	175.6	63.5	224.8	48.5	78.0
	103	582.1	251.5	142.1	188.5	32.4	57.0
	107	457.4	130.9	88.1	238.4	52.1	73.0
	109	379.5	124.0	90.5	165.0	43.5	64.6
	Avg.	478.03	167.48	92.21	218.35 b	46.11 b	70.15 a

a, b = Values within each column sharing a common letter do not differ significantly ($P<.05$).

[1] Total for 6 days.

in the nitrogen retained as a percentage of intake for the ammonium VFA rations, suggest that the supplemented nitrogen was absorbed and retained by the animal for use. The nitrogen retained as a percentage of intake for propionate was greater than for acetate but differences were not significant. The nitrogen retained as a percentage absorbed is an indicator of the efficiency with which the body uses the absorbed nitrogen. Ammonium propionate was used somewhat more efficiently than the ammonium acetate.

Dry matter digestibility was improved significantly over the control ration by addition of both VFA salts (Table 5). The crude fiber digestibility was also increased by the addition of the VFA salts but not significantly. This supports findings that addition of nitrogen to ruminant rations low in protein will enhance dry matter and crude fiber digestibility (Helmer and Bartley, 1971). There was little, if any, difference between the three rations in digestibility of ether extract.

Protein digestibility was significantly improved by addition of ammonium salts to the control ration. A small improvement in protein digestibility of propionate over acetate was noted but it was not significant. These data suggest that nitrogen added in the ammonium form was utilized by the animal.

The additional energy from the VFA was also utilized as shown by the significant differences in energy digestibility between the control ration and the rations containing the ammonium salts. Ammonium salts of VFA can increase energy efficiency and dry matter digestibility.

Table 5. Effect of supplementation of a basal ration with Amace or Ampro on nutrient digestibility.

Treatment	Animal number	Digestibility (%)[1] Dry matter	Crude fiber	Ether extract	Protein	Energy
Basal	99	66.5	49.4	73.2	42.8	63.9
	100	59.1	29.9	75.2	49.7	56.7
	102	58.1	18.9	66.0	49.9	54.2
	103	57.4	19.1	58.7	48.5	54.4
	107	61.3	21.6	67.7	51.5	57.7
	109	62.3	31.5	70.7	54.8	59.4
	Avg.	60.78 a	28.4 a	68.58 a	49.53 a	57.71 a
Amace	99	65.4	37.5	52.3	51.7	61.0
	100	61.3	22.8	65.7	61.8	58.2
	102	67.0	35.5	69.0	63.2	63.3
	103	65.4	25.7	71.1	61.3	61.4
	107	66.0	42.8	74.0	57.8	60.2
	109	71.5	38.1	75.5	72.2	69.6
	Avg.	66.1 b	33.73 a	67.9 a	61.33 b	62.28 b
Ampro	99	69.7	38.3	77.9	69.6	68.7
	100	71.3	23.0	67.4	64.9	60.3
	102	68.2	44.7	71.5	62.2	63.9
	103	58.3	22.1	71.8	57.0	56.3
	107	66.7	38.2	63.4	71.6	63.9
	109	69.6	31.1	70.9	67.4	66.0
	Avg.	67.3 b	32.9 a	70.5 a	65.5 b	63.2 b

a, b = Values within each column sharing a common letter do not differ significantly ($P<.05$).

[1] Average for 6 days.

The results obtained show that ammonium salts of VFA can be used as a supplemental form of protein for cattle rations. The ammonia in ammonium salts of VFA is used to improve the protein status of the animal, as demonstrated by improvement of nitrogen absorption, retention of absorbed nitrogen, and crude protein digestibility.

PART II. UTILIZATION OF HEMICELLULOSE EXTRACT FOR RUMINANTS

REVIEW OF LITERATURE

As the human demand for cereal grains increases, ruminant animals will become more important because of their ability to utilize materials unfit for human consumption. An example of materials which ruminants can utilize is industrial byproducts. One such byproduct from the wood industry is Masonex (a hemicellulose extract from the Masonite Company). Masonex, after concentration by dehydration, has the appearance and consistency of cane molasses. Research indicates that Masonex has possible urease inhibiting characteristics, which could prove valuable in slowing urea breakdown and reducing ammonia toxicity from rapid hydrolysis of urea in the rumen.

Conversion of Urea to Microbial Protein in the Rumen

Nonprotein nitrogen consumed by ruminant animals can be used to synthesize microbial proteins. The nutrient source for microbial protein synthesis has been shown to be the ammonia produced in the rumen (Land and Virtanen, 1959; Phillipson et al., 1959).

The conversion of urea to microbial protein was definitely established in studies in which nitrogen balance (Fingerling et al., 1937; Harris and Mitchell, 1941a; Lofgreen et al., 1947; Loosli and McCoy, 1943), growth (Bartlett and Cotton, 1938; Harris and Mitchell, 1941a; Hart et al., 1939; Pope et al., 1952; Work and Henke, 1939), milk yield (Archibald, 1943; Owen et al., 1943; Rupel et al., 1943), and body composition

(Harris and Mitchell, 1941b; Hart et al., 1939; Loosli and McCay, 1943; Watson et al., 1939) were all improved by addition of urea to cattle rations.

Urease Enzyme

Urease from jackbean meal was the first enzyme to be obtained in a crystalline state. Urease is inhibited by large amounts of its own substrate (Larson and Kallios, 1950) and is produced by over 200 species of bacteria and some plants. Certain seeds such as jackbean, contain relatively large concentrations of urease (Sumner and Somers, 1953). Larson and Kallios (1954) stated that the lower temperature of activation displayed by bacterial urease accounts for its greater activity than urease from other sources.

Van Slyke and Cullen (1914) indicated that ureolytic activity increased as the pH of the medium was increased. Howell and Sumner (1934) found the activity of urease to be dependent on temperature, pH, type of buffer, urea concentration, and salt concentration of the solution.

Wang and Tarr (1955) gave three possible mechanisms for urea hydrolysis: 1) carbonic acid mechanism in which urea is hydrolyzed to carbamic acid, then to carbonic acid, and then to carbon dioxide and water; 2) carbamic acid mechanism in which urea is hydrolyzed to carbamic acid, then to carbon dioxide and water; 3) carbon dioxide mechanism in which urea is directly hydrolyzed to carbon dioxide and ammonia.

Bacterial urease is inactivated rapidly by dialysis, a pH below 5.2, and in the presence of organic solvents. The affinity of urease

for urea is highest at pH 7.7 (Larson and Kallios, 1954). Lysed bacterial cells hydrolyze five times as much urea as intact cells. The activity of urease is reduced greatly at the pH which is optimum for bacterial growth; therefore, bacterial cells compensate by producing more urease at that pH (Larson and Kallios, 1954).

Hydrolysis of 246 mg urea per hour per ml of rumen contents was observed in short term in vitro incubations (Muhrer and Carroll, 1964). Micrococci was found at a concentration of 10^4 per ml and actinomycete strains at a concentration of 10^4 per ml in the rumen. Both organisms possessed ureolytic activity. It was indicated that a low-level of urease activity was found in many species instead of a few highly active species. Very few isolated rumen strains have been found to hydrolyze urea in significant quantities (Akkada and Blackburn, 1963; Blackburn and Hobson, 1962).

Gibbons and McCarthy (1957) studied rumen liquor fractions and found that "large" bacteria produced 346 uM of ammonia nitrogen per hour per mg nitrogen, while "small" bacteria and whole rumen liquor fractions produced 46 uM of ammonia nitrogen per hour per mg nitrogen. Cell free rumen fluid did not exhibit ureolytic activity, thus it was suggested that urease was a bacterial secretion. Jones et al. (1964a) showed that 64% of the total ruminal urease activity was associated with larger microorganisms which centrifuged out of solution at 1200 x g.

Lyubimov (1955) indicated that living ureolytic bacteria do not exude urease into the surrounding medium. He observed that most of the urease in Micrococcus ureae and Proteus vulgaris was bound in the bacterial cell and given out only after death and decomposition of the

cell. Additional evidence that urease is intracellular was provided by several workers (Lattimer et al., 1961; Seneca et al., 1962; Seneca et al., 1961; Brent and Richardson, 1967).

Federova (1965) studied the bond of urease with the bacterial cell using Pasteurilla pseudotuberculosis, Proteus vulgaris, and Pseudomonas aeruginosa. One fraction of urease was released in the course of bacterial growth, a second fraction was labile, bound by the cell surface and easily separated by saline washings, and a third fraction was extracted only after disruption of the cell. Larson and Kallios (1954) found that resting Bacillus pasteuri cells hydrolyzed urea only one-fifth as rapidly as an equivalent weight of lysed cells.

Urease Inhibition

Brent and Adepoju (1967) ran in vitro tests on acetohydroxamic acid (200 mcg per ml rumen fluid) in rumen fluid obtained from a steer and reported complete inhibition of ammonia release. A 50% decrease in ammonia was obtained with the addition of 10 mcg of the acid per ml of rumen fluid. In vivo studies found a lowered ammonia level up to 3 h after feeding the acid.

Alloxenic acid was shown to be a strong inhibitor of urease (Gray et al., 1936). The inhibition was found to be non-competitive in nature. Streeter et al. (1969) administered 500 mg of acetohydroxyamic acid to wethers and found a decrease in ruminal ammonia produced as compared to control animals. The nitrogen retention as a percentage of intake was 5.2% better in lambs receiving the acid.

Shaw (1953) found silver ion to be an extremely efficient inhibitor of urease. In general, metal ions forming the most insoluble sulfides were also the strongest urease inhibitors. It was suggested that chelation may be involved with inhibition of urease by metal ions. Shaw (1953) also reported that metal ion inhibition was non-competitive and dependent on the square of the inhibitor concentration. It was found that the SH groups in urease are involved in maintaining correct structural relationships in the enzyme protein and are not integral parts of catalytically active sites. Jones et al. (1964b) found that rumen bacterial urease is an ion dependent intracellular enzyme. Their data showed ureolytic activity to be stimulated by Mn^{++}, Mg^{++}, Ca^{++}, Sr^{++}, and Ba^{++} and inhibited by Na^{+}, K^{+}, and Co^{++}.

Hemicelluloses

Hemicellulose is the commonly used name for the polysaccharides of low molecular weight which occur in plant tissues with cellulose and can be extracted with water or aqueous alkali (Wenzl, 1970; Timell, 1964). They contain both hexoses and pentoses and may have branched-chain structures, the chains being much shorter in hemicellulose than in cellulose. The average degree of polymerization in hemicellulose is 150 (Schuerch, 1963; Wise, 1952).

The principal form of hemicelluloses are chains of sugar residues (Timell, 1964). The principal residues are: D-xylose, D-mannose, D-glucose, D-galactose, L-arabinose, 4-O-methyl D-glucuronic acid, D-glucuronic acid,

and L-rhamnose, L-fructose, and D-methylated sugars (Schuerch, 1963; Wise, 1952). Hemicelluloses also contain other groups such as uronic acids and acetyl groups that are not present in cellulose (Farmer, 1967). Also associated with hemicellulose extract are phenolic substances such as lignin, tannins, and phlobaphenes (Browning, 1963).

Phenolics

Phenolic compounds are substances containing a hydroxyl substituent on an aromatic ring. Phenolics are soluble in neutral organic solvents, cold water, hot water, and are sometimes volatile with steam (Browning, 1963; Tsoumis, 1968; Wenzl, 1970; Thomson, 1964). Phenolics, especially in the form of tannins, have been shown to decrease deamination of proteins, decrease ammonia production, and enhance nitrogen utilization in the rumen (Driedger and Hatfield, 1972).

Lees and Nelson (1967) reduced the solid content of a hot water extract of Eucalyptus siebei and found that 65% of the solids were tannins. Shaposhnikov et al. (1966) applied gas liquid chromatography to the analysis of monohydric phenols and found it suitable for analyzing mixtures of phenols obtained during chemical processing of woods. Gel filtration is also employed in the separation of tannins. The process excludes tannins of molecular weight over 1,100 and is carried out on a Sephadex G-25 column eluted with 50% aqueous acetone (Porter, 1972).

Zelter and Leroy (1966) treated five peanut and soybean meal samples with aqueous solutions of tannins (13-25%) and dried them.

In vitro studies showed that untreated proteins were degraded rapidly in the rumen while tannin treated proteins escaped degradation. Sheep fed tannin-treated proteins produced only 50% of the ammonia that was produced by sheep fed untreated proteins.

Delort-Laval and Zelter (1968) reported that tannin-treated peanut and linseed meals only slightly increased efficiency of nitrogen utilization in experimental animals.

Hatfield et al. (unpublished, 1968) found that steers fed tannic acid treated soybean meal gained more weight than did steers fed urea or untreated soybean meal. An in vitro test with 2% added tannic acid resulted in a 54.1% reduction in hydrolysis of urea over a 3 h test period over the control (Behnke, 1975). The added acid also inhibited the release of ammonia.

Driedger and Hatfield (1972) found that soybean meal treated with a 5% tannic acid solution produced only 57.6% as much ammonia in lambs as did untreated soybean meal. The optimum protective response was obtained with soybean meal treated with 10% tannin. Tannin added to soybean meal or peanut meal did not affect peptic proteolysis. Van Buren and Robinson (1969) reported that the tannin-protein complex is not stable at gastric pH, but is stable at the more neutral pH of the pancreatin digesta.

Driedger and Hatfield (1972) reported that lambs eating tannin treated soybean meal retained significantly greater amounts of dietary nitrogen than did those eating untreated soybean meal or urea supplements.

Ke (1973) analyzed phenolic compounds in Masonex by the Folin-Denis method and found 3.4% phenolics in the lead precipitate of freeze dried Masonex.

Hemicellulose Extract (Masonex)

A hemicellulose extract (Galloway, 1975) of the Masonite Company is produced as a byproduct of Masonite's production of hardboard. Wood chips are charged into a steam digester and subjected to pressures up to 600 psi for 60 sec. The pressure is released, causing the fibers to separate. The wood fibers are washed with water and the water soluble solution is dried to approximately 60% solids (Galloway, 1975).

A typical analysis of Masonex shows it to contain 55% carbohydrate, .5% protein and .5% fat. Ash is only 6%. Metabolizable energy for ruminants is 890 kcal per pound. Masonex contains 10% simple sugars, 35% after hydrolysis. Distribution of the sugars after hydrolysis is: glucose 14%; Mannose 27%; galactose 8%; arabinose 5%; xylose 46%. Masonex typically has a pH of 5.0 (Galloway, 1975).

McLaren (1974) ran in vitro tests on a mixture of Masonex and urea and obtained a microbial protein synthesis of 10.86 mg nitrogen in 6 h. This was approximately 8 mg less nitrogen than produced by a urea control in the same time. Masonex added to the urea significantly increased retention of absorbed nitrogen in rats over a control ration without Masonex.

Lambs consumed significantly more feed when fed rations containing Masonex or a sugar fraction of Masonex than when consuming rations without Masonex (Behnke, 1975). The percentage of nitrogen intake which was

retained and the percentage of nitrogen absorbed which was retained was significantly higher for the ration containing Masonex or Masonex sugar fractions than for the basal ration without Masonex.

With 6% California Masonex added to an in vitro substrate mix with urea, production of ammonia was only 61.8% that of a control substrate without Masonex (Behnke, 1975). An ethyl acetate extract of Masonex added to a lamb ration resulted in greater feed intake than when Masonex was added. The ethyl acetate extract of Masonex produced no detrimental effect in vitro on amylolytic activity.

Feed Intake and Growth on Masonex

Beef cattle consumed 1.1 kg per day more feed when Masonex was added to the ration than when cane molasses was added (Masonite Corp., 1975). A similar report from Kansas State University showed almost no difference in feed consumption or efficiency between cane molasses and Masonex (Masonite Corp., 1975).

Algeo and Putnam (1975) found that feed consumption of heifers on a Masonex supplemented ration was approximately .5 kg per day per heifer greater than that of heifers on a beet molasses supplemented ration. Bartley et al. (1975) fed a control ration with no molasses, a ration with cane molasses, a ration with liquid Masonex, and a ration with dried Masonex to lactating dairy cows and found no significant differences in palatability or intake between the supplemented rations. All supplemented rations were significantly higher in intake than the ration with no molasses added.

Perry et al. (1975) fed cattle free choice on a complete mixed fattening ration supplemented with: all cane molasses, no Masonex; 75% cane molasses, 25% Masonex; 50% cane molasses, 50% Masonex; 25% cane molasses, 75% Masonex; and 100% Masonex. No differences in nutritional value were found. Perry et al. (1975) also compared the ration with 100% cane molasses to a ration with 100% dried Masonex added. Cattle on the ration with dried Masonex added gained 14% more rapidly on 7% less feed than those on the ration with added cane molasses.

Boren et al. (1975) added 10% cane molasses or 10% Masonex to a ration of soybean meal, rolled sorghum grain, ground rice hulls and urea and found very little difference in rate of gain, feed intake, feed efficiency, or carcass weight between cattle fed the two rations. Algeo (1975) found no significant differences between Masonex and beet pulp in body weight gains, but did obtain a higher feed conversion ratio for Masonex fed cattle. Algeo et al. (1975) ran in vitro tests on fattening rations to compare cane molasses, beet molasses, and Masonex. No difference was found in the capacity of any treatment to support rumen fermentation. The net production of energy from VFA did not differ due to the source of energy.

Virtanen (1975) fed cows over a period of 2 to 3 yr on diets containing Masonex and concluded that a large part (30 to 40%) of the feed of milking cows can be made up of forestry products.

Magruder et al. (1953) conducted a 90 day feeding trial with yearling heifers in which 4.5 kg of ammoniated Masonex replaced peanut

skins and soybean meal. The control grain ration required slightly less feed per pound of gain but not significantly so. The data indicated that the heifers were able to use nitrogen from the ammoniated Masonex supplemented feed as well as the soybean meal supplemented feed.

Williams et al. (1975) compared Masonex and cane molasses, and mixtures of the two as carbohydrate sources for urea supplenented diets. They found that Masonex and cane molasses resulted in a more efficient diet when added together in a ration in equal parts than when added separately.

EXPERIMENTAL PROCEDURE

Masonex has been shown to have urease inhibiting characteristics. This property could possibly be exploited in liquid supplements containing urea by giving better utilization of the urea and by reducing the rate of hydrolysis of urea to ammonia in the rumen thereby reducing the risk of ammonia toxicity.

This study was undertaken to determine the effects, in vitro, of Masonex on urease inhibition, ammonia release, and protein synthesis.

On the morning of an experiment, rumen fluid was obtained from a rumen fistulated animal fed a ration of 4.5 kg alfalfa hay and 4.5 kg concentrate daily. The rumen fluid was filtered through four layers of cheesecloth and an initial pH was determined. Initial ammonia and urea concentrations were determined by the Conway method (Conway, 1962). Initial crude protein content of the rumen fluid and feed blanks was

determined by the Kjeldahl method (AOAC, 1970), having first centrifuged 30 ml samples at 25,400 x g three times. The precipitate was washed with methanol between each centrifugation to remove soluble nitrogen (Barr, 1974). All samples were determined in duplicate.

Protein synthesis determinations were prepared by placing .9 g Masonex or cane molasses and .1 g urea, or 1 g Starea, with 20 ml buffer, and 10 ml rumen fluid in plastic centrifuge tubes and incubating at 39 C. Caps were placed in the tubes and vented with Bunsen valves to allow escape of fermentation gas. At the end of fermentation, the tubes were centrifuged and washed as described previously and Kjeldahl nitrogen determined to give final crude protein. The microbial protein synthesis was estimated by subtracting the initial crude protein concentration in the substrate and in the rumen fluid from the final crude protein concentration after fermentation.

The method of el-Shazly and Hungate (1965) was used to estimate the rate of fermentation which is measured by gas production. Gas production is considered to measure the fermentability of the substrate because it is the sum of the fermentation gases (carbon dioxide and methane) and gas produced by volatile fatty acids in a bicarbonate buffer. The actual method used for gas production was the Barr (1974) modification of the el-Shazly and Hungate (1965) method.

Gas production was measured in 250 ml centrifuge bottles in which 4.5 g Masonex or cane molasses and .5 g urea had been placed. Starea (5.0 g), a mixture of cooked starch and urea, was also used as a control because of its high fermentability characteristics (Helmer, 1969). One

hundred ml of buffer (pH 6.8) consisting of: 61.2 g potassium phosphate; 3.0 g magnesium sulfate; 7.5 g sodium chloride; and .75 g calcium chloride in 15 l of water, and 50 ml rumen fluid were added to the bottles and the bottles were placed in a 39 C water bath. Gas production was measured by water displacement. Readings of gas production were taken every 30 min. The bottles were swirled every 30 min to insure mixing of the microorganisms and the substrate. Samples were taken from the bottles to determine initial ammonia and urea concentrations and again after 6 hr to determine final ammonia and urea concentrations.

RESULTS AND DISCUSSION

After fermentation, the concentration of ammonia was greater for Starea than for Masonex or cane molasses (Table 1), even though the initial urea concentration was lower for Starea than for the other samples. This decrease (not significant) in ammonia would suggest that the Masonex samples and cane molasses might have inhibited urease to a greater extent than did Starea. The increase in ammonia production corresponding to the increase in age of the Masonex samples would suggest a loss of the inhibitory factor due to aging. Degradation of urea was closely related to ammonia production with the Starea sample showing a significantly greater degradation of urea than all other samples. The 1969 Masonex sample showed more urea degradation than the 1975 Masonex samples, also indicating loss of the inhibitory factor with age. The Masonex samples had slightly more urea degradation

Table 1. Effect of Starea, Masonex, or cane molasses on urea degradation and ammonia release in vitro (6 h fermentation).

Treatment	Number of determinations	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Urea degradation
		(mg N/100 ml)					%
Corn Starea	8	6.86	72.99	66.15 a	101.12	44.97 a	62.7 a
Masonex (Oct. '75)	7	5.71	55.25	49.54 a	145.4	89.26 b	38.6 b
Masonex (July '75)	12	6.33	55.94	47.18 a	149.9	90.85 b	40.03 b
Masonex (1969)	7	5.90	62.59	56.69 a	145.6	82.33 b	43.6 b
Cane molasses (1975)	10	8.26	56.77	48.48 a	151.49	99.64 b	34.2 b

a, b = Values within each column sharing a common letter do not differ significantly ($P < .05$).

than cane molasses suggesting in this case a somewhat greater urease inhibition for the cane molasses. There was no significant difference in urea breakdown between Masonex samples or between cane molasses and Masonex.

The microbial protein synthesis was significantly greater for Starea than any other sample (Table 2). The July 1975 and the 1969 Masonex samples had a significantly lower protein synthesis than did the October 1975 Masonex samples. The cane molasses sample showed a lower protein synthesis than the October 1975 Masonex and a greater protein synthesis than the July 1975 and 1969 Masonex samples but the differences were not significant in either case.

Table 2. Effect of Starea, Masonex, or cane molasses on protein synthesis and gas production in vitro (6 h fermentation).

Treatment	Number of determinations	Protein synthesis	Gas production	Final pH
		(mg/100 ml)	(ml)	
Corn Starea	8	24.49 a	203.4 a	4.82
Masonex (Oct. '75)	7	17.01 b	89.3 b	6.26
Masonex (July '75)	12	13.41 c	88.7 b	6.35
Masonex (1969)	7	8.55 c	78.4 b	6.33
Cane molasses (1975)	10	14.7 bc	169.7 a	5.31

a, b, c = Values within each column sharing a common letter do not differ significantly ($P < .05$).

Gas production, a measure of the microbial fermentability of the substrate, was significantly lower for the Masonex samples than for cane molasses or Starea (Table 2). The 1969 Masonex sample was slightly, but

not significantly less fermentable than the 1975 samples. The final pH is an indication of production of volatile fatty acids and was related to fermentability as demonstrated by the gas production (Table 2). The Masonex samples had the highest final pH with no difference between different sample dates. Cane molasses had the next lowest pH, indicating a greater production of volatile fatty acids, followed by the Starea which had the lowest final pH.

The low pH attained for the Starea and cane molasses substrates indicated completeness of fermentation after 6 h because rumen microorganisms would not be active at a pH value approaching 5. However, the pH of the Masonex samples after 6 h of fermentation were approximately 6.3, indicating incomplete fermentation. The Masonex and Starea samples were therefore fermented for both 6 and 9 h periods (Table 3).

Table 3. Protein synthesis, ammonia production, and urea degradation in vitro for 9 h vs 6 h fermentation.

Treatment[1]		Protein synthesis	Increase in protein from 6 h to 9 h	Final NH_3-N	Final urea	Urea degradation
		(mg/100 ml)	%	(mg N/100 ml)		%
Corn Starea	9 h	25.61	26.2	87.4	7.45	91.97
	6 h	20.3		69.96	52.72	59.6
Masonex (Oct., '75)	9 h	32.64	93.25	120.5	8.81	94.09
	6 h	16.89		52.14	92.78	37.2
Masonex (July, '75)	9 h	32.13	103.0	125.9	14.22	90.5
	6 h	15.82		53.83	91.62	39.7
Masonex (1969)	9 h	20.97	142.7	132.73	14.9	90.0
	6 h	8.64		58.83	84.65	42.7

[1] Each value is an average of 4 determinations.

Fermentation for 9 h only increased microbial protein synthesis by 26.2% for Starea, whereas protein synthesis was increased by 93 to 143% for the Masonex samples. This suggests that the urease inhibition in Masonex is broken down by the rumen microorganisms by 9 h. An in vitro test determining the urea breakdown and ammonia production in Masonex or Starea samples indicated that in 9 h fermentation, the Masonex samples were almost identical in degradation of urea to the Starea sample. However, these results were based on a small number of in vitro tests and should be tested again to confirm the results.

From the results of this study it is apparent that Masonex is fermented much more slowly by rumen microorganisms than either Starea or cane molasses. Even though fermented more slowly, Masonex, if fresh, appears to assist in better microbial protein synthesis in vitro, than cane molasses. These in vitro findings can be related somewhat to the work of Perry et al. (1975) in which rations supplemented with Masonex supported more rapid gain on less feed than did cane molasses when fed to fattening cattle.

Masonex did show urease inhibiting properties, with approximately 20% less urea degradation for Masonex than for Starea in a 6 h in vitro test. This urease inhibition and fermentability declined with age. The urease inhibition was lost between 6 and 9 h of fermentation.

Although Masonex has been found to have urease inhibiting characteristics by other workers (Galloway, 1975; McLaren, unpublished, 1974), the low fermentability indicates that it would be best used when mixed with a highly fermentable substrate such as cane molasses to assure best utilization of urea (Williams et al., 1975; Areas et al., 1951).

LITERATURE CITED

Akkada, A. R. and T. H. Blackburn. 1963. Some observations on the nitrogen metabolism of rumen proteolytic bacteria. J. Gen. Microbiol. 31:461.

Algeo, J. W. 1975. The comparative feeding value of hemi-cellulose extract and molasses for fattening heifers. Special report to Masonite Corp., Chicago, Ill.

Algeo, J. W., T. P. Brannum, and A. G. Hibbit. 1975. An in vitro comparison of cane molasses, beet molasses and Masonex in beef rations. Special report to Masonite Corp., Chicago, Ill.

Algeo, J. W. and E. S. Putnam. 1975. The comparative feeding value of hemi-cellulose extract (Masonex) and molasses for fattening heifers. Special report to Masonite Corp., Chicago, Ill.

A.O.A.C., Association of Official Analytical Chemists. Official methods of analysis. 11th edit. The Association. Washington, D. C. (1970).

Archibald, J. G. 1943. Feeding urea to dairy cows. Mass. Agr. Expt. Sta. Bulletin 406.

Arias, C., W. Burroughs, P. Gerlough, and R. M. Bethke. 1951. The influence of different amounts and sources of energy upon in vitro urea utilization by rumen microorganisms. J. Animal Sci. 10:683.

Armstrong, D. G., and K. L. Blaxter. 1957. Heat increment of steam volatile fatty acids in fasting sheep. Brit. J. Nutrition 11:247.

Armstrong, D. G., K. L. Blaxter and N. M. Graham. 1957. The heat increments of mixtures of steam-volatile fatty acids in fasting sheep. Brit. J. Nutrition 11:392.

Armstrong, D. G., K. L. Blaxter, N. M. Graham and F. W. Wainman. 1958. The utilization of the energy of two mixtures of steam-volatile fatty acids by fattening sheep. Brit. J. Nutrition 12:177.

Baile, C., and J. Meyer. 1968. Intravenous versus intraruminal injections of acetate on feed intake of goats. J. Dairy Sci. 51:1490.

Barr, G. W. 1974. In vitro rumen fermentation techniques for studying urea utilization in the bovine rumen. Ph.D. dissertation. Kansas State University, Manhattan.

Bartlett, S. and A. G. Cotton. 1938. Urea as a protein substitute in the diet of young cattle. J. Dairy Res. 9:263.

Bartley, E. E., E. L. Farmer, H. B. Pfost, and A. D. Dayton. 1975. Comparative value of dry and liquid hemi-cellulose extract and liquid cane molasses for lactating dairy cows. Special report to Masonite Corp., Chicago, Ill.

Bartley, E. E., D. W. Webb, L. G. Helmer, and F. W. Boren. 1973. Methods of feeding volatile fatty acids to dairy cows. J. Dairy Sci. 56:643.

Behnke, K. C. 1975. Investigations of biological effects of phenolic materials from hemicellulose extract. Ph.D. dissertation, Kansas State University. Manhattan.

Belasco, S. P., and A. N. Bessman. 1955. New nitrogen feed compounds for ruminants; a laboratory evaluation. J. Animal Sci. 13:601.

Bergman, E. N., R. S. Reid, M. G. Murray, J. M. Brockway, and F. G. Whitelaw. 1965. Interconversions and production of volatile fatty acids in the sheep rumen. Biochem. J. 97:53.

Blackburn, T. H. and P. N. Hobson. 1962. Further studies on the isolation of proteolytic bacteria from the sheep rumen. J. Gen. Microbiol. 29:69.

Blaxter, K. L. 1962. The Energy Metabolism of Ruminants. Charles C. Thomas, Springfield, Ill.

Bondarenko, G. A. and I. K. Slesarev. 1965. Effect of ammonium acetate on increasing milk fat, intermediary metabolism and processes of rumen digestion in Jersey and Friesen cows. Nutr. Abstr. and Reviews 35:5820 (Abstr.).

Boren, F. W., H. B. Pfost, E. F. Smith, and D. Richardson. 1975. Cane molasses and hemicellulose extract in rations for finishing steers. Special report to Masonite Corp., Chicago, Ill.

Brent, B. E. and A. Adepoju. 1967. Effect of acetohydroxamic acid on rumen urease. J. Animal Sci. 26:1482.

Brent, B. E. and D. Richardson. 1967. Apparent intracellular nature of rumen urease. J. Animal Sci. 26:914.

Browning, B. L. 1963. The composition and chemical reactions of wood. In B. L. Browning (ed.) The Chemistry of Wood. Interscience Publishers, New York.

Bull, L. S., J. T. Reid, and D. E. Johnson. 1970. Energetics of sheep concerned with the utilization of acetic acid. J. Nutrition 100:262.

Conway, E. J. 1962. Microdiffusion Analysis and Volumetric Error. 4th ed. Crosby Lockwood and Sons, Ltd., London.

Delort-Laval, J. and S. Z. Zelter. 1968. Improving the nutritive value of proteins by tanning process. Paper 126. Proceedings of second world conference on animal production, College Park, Maryland.

Dinius, D. A., D. L. Hill, and C. H. Noller. 1968. Influence of supplemental acetate feeding on the voluntary intake of cattle fed ground corn silage. J. Dairy Sci. 51:1505.

Driedger, A. and E. E. Hatfield. 1972. Influence of tannins on the nutritive value of soybean meal for ruminants. J. Animal Sci. 34:465.

El-Shazly, K. and R. E. Hungate. 1965. Fermentation capacity as a measure of net growth of rumen microorganisms. Applied Micro. 13:62.

Essig, H. W., E. E. Hatfield, and B. C. Johnson. 1959. Volatile fatty acid rations for growing lambs. J. Nutrition 69:135.

Essig, H. W., U. S. Garrigus, and B. C. Johnson. 1962. Studies on the levels of volatile fatty acids for growing and fattening lambs. J. Animal Sci. 21:37.

Farmer, R. H. 1967. Chemistry in the Utilization of Wood. Pergamon Press: New York.

Federov, L. S. 1965. The bond of urease with the bacterial cell. Chem. Abstracts 64:5474.

Fingerling, G., B. Hientzsch, H. Kunze and K. Reifgerst. 1937. Substitution of urea for proteins in cattle feed. Landw. vers sta. 128:221.

Galloway, D. F. 1975. Masonex - the hemicellulose extract factor. Special report to Masonite Corp., Chicago, Ill.

Gibbons, R. J. and R. D. McCarthy. 1957. Obligately anaerobic urea hydrolyzing bacteria in the bovine rumen. J. Dairy Sci. 40:635 (abstr.).

Gray, C. T., M. S. Brooke, and J. C. Gerhart. 1959. Inhibition of urease by alloxan and alloxanic acid. Nature 184:1936.

Harris, L. E. and H. H. Mitchell. 1941a. The value of urea in the synthesis of protein in the paunch of the ruminant. I. In maintenance. J. Nutrition 22:167.

Harris, L. E. and H. H. Mitchell. 1941b. The value of urea in the synthesis of protein in the paunch of the ruminant. II. In growth. J. Nutrition 22:183.

Hart, E. B., G. Bohstedt, H. J. Deobald, and M. I. Wegner. 1939. The utilization of simple nitrogen compounds such as urea and ammonium bicarbonate by growing calves. J. Dairy Sci. 22:785.

Hatfield, E. E. 1969. Selected topics related to the amino acid nutrition of the growing ruminant. Presented at 10th Annual Ruminant Nutrition Conference held in conj. with Fed. of Amer. Soc. for Exp. Biol. Atlantic City, New Jersey.

Helmer, L. G. 1969. Effect of an expansion processed mixture of grain and urea on lactating dairy cows and on nitrogen utilization by rumen microorganisms. Ph.D. dissertation, Kansas State University, Manhattan.

Helmer, L. G. and E. E. Bartley. 1971. Progress in the utilization of urea as a protein replacer for ruminants. A review. J. Dairy Sci. 52:25.

Holter, J. B., C. W. Heald, and N. F. Colovas. 1970. Heat increments of steam-volatile fatty acids infused separately and in a mixture into fasting cows. J. Dairy Sci. 53:1241.

Howell, S. F. and J. B. Sumner. 1934. The specific effects of buffers upon urease activity. J. Biol. Chem. 104:619.

Jones, G. A., R. A. Macleod, and A. C. Blackwood. 1964a. Ureolytic rumen bacteria. I. Characteristics of the microflora from a urea fed sheep. Canadian J. Microbiol. 10:371.

Jones, G. A., R. A. Macleod, and A. C. Blackwood. 1964b. Ureolytic rumen bacteria. II. Effect of inorganic ions on urease activity. Canadian J. of Microbiol. 10:379.

Jones, G. M., E. Donefer, and J. I. Elliot. 1970. Feeding value of propionic acid treated high moisture corn. MacDonald Journal 31(4):75.

Kay, M., B. F. Fell, and R. Boyne. 1969. The relationship between the acidity of the rumen contents and rumenitis, in calves fed on barley. Res. Vet. Sci. 10:181.

Kay, M., N. A. Macleod, G. McKiddie, and E. B. Phillip. 1967. The nutrition of the early weaned calf. 10. The effect of replacement of fish meal with either urea or ammonium acetate on growth rate and nitrogen retention in calves fed ad libitum. Animal Prod. 9:197.

Ke, H. 1973. Studies on the carbohydrates and phenolic compounds in Masonex, a complex commercial hemicellulose extract. Ph.D. dissertation. Kansas State University, Manhattan.

Land, H. and A. I. Virtanen. 1959. Ammonium salts as a nitrogen source in the synthesis of protein by the ruminant. Acta Chem. Scand. 13:489.

Larson, A. A. and R. E. Kallios. 1954. Purification and properties of bacterial urease. J. Bacteriol. 68:67.

Lattimer, J. K., H. Seneca, H. H. Zinssex, and J. T. Donovan. 1961. Drug resistant bacteria made drug susceptible by enzyme inhibitors. J. Amer. Med. Assoc. 178:764.

Lees, G. J. and Nelson, P. F. 1967. An examination of hot water extracts of Eucalyptus sieberi. Chem. Abstracts 67:33957d.

Lofgreen, G. P., J. K. Loosli, and L. A. Maynard. 1947. The influence of protein source upon nitrogen retention by sheep. J. Animal Sci. 6:343.

Loosli, J. K. and C. M. McCoy. 1943. Utilization of urea by young calves. J. Nutrition 25:197.

Lyubimov, V. I. 1955. The splitting of urea in bacteria as an intracellular process. Chem. Abstracts. 49:16067.

Magruder, N. D., C. B. Knodt, and P. S. Williams. 1953. Ammoniated feeds. Ammoniated industrial byproducts in dairy heifer rations. Ag. and Food Chem. 15:944.

Martin, W. G., H. A. Ramsey, G. Matrone, and G. H. Wise. 1959. Responses of young calves to a diet containing salts of volatile fatty acids. J. Dairy Sci. 42:1377.

Matrone, G., H. A. Ramsey, and G. H. Wise. 1959. Effect of volatile fatty acids, sodium and potassium bicarbonates in purified diets for ruminants. Proc. Soc. Exp. Biol. Med. 100:8.

McCollough, M. E. and W. W. G. Smart, Jr. 1970. Some effects of urea, sodium acetate and whey on ruminant fermentations. Proc. Georgia Nutrition Conf.

McCollough, M. E., L. R. Sisk, and W. W. G. Smart. 1969. Sodium acetate and sodium propionate as additives to all-in-one rations for milk production. J. Dairy Sci. 52:1605.

McLaren, G. A. 1974. Influence of Masonex hemicellulose extract and corn cob acid-resistant hemicellulose (ARH) factor on in vitro rumen microbial protein synthesis. Unpublished data.

Montgomery, M. J., L. H. Schultz, and B. R. Baumgardt. 1963. Effect of intraruminal infusion of volatile fatty acids and lactic acid on voluntary hay intake. J. Dairy Sci. 46:1380.

Muhrer, M. E. and E. J. Carroll. 1964. Urea utilizing microorganisms in the rumen. J. Animal Sci. 23:885. (Abstr.)

N. R. C. 1970. Nutrient Requirements of Domestic Animals, No. 3. Nutrient Requirements of Dairy Cattle. National Research Council, Washington, D. C.

Orskov, E. R. and D. M. Allen. 1966. I. Acetate, propionate and butyrate as sources of energy for young growing lambs. Brit. J. Nutrition. 20:295.

Perry, T. W., R. J. Hiller, J. P. Shepard, and W. M. Beeson. 1975. Comparative value of cane molasses and hemicellulose extract for fattening beef cattle. Special report to Masonite Corp., Chicago, Ill.

Phillipson, A. T., N. J. Dobson, and T. H. Blackburn. 1959. Assimilation of ammonia nitrogen by rumen bacteria. Nature 183:402.

Poole, D. A. and D. N. Allen. 1970. Utilization of salts of volatile fatty acids by growing sheep. 5. Effects of type of fermentation of the basal diet on the utilization of salts of acetic acid for body gains. Brit. J. Nutrition 24:695.

Pope, L. S., F. Baker, W. D. Gallup, and C. K. Whitehair. 1952. Urea and cottonseed meal as supplements for lamb fattening rations. Okla. Agr. Expt. Sta. Misc. Publ. MP-27:53.

Porter, L. J. and R. D. Wilson. 1972. Separation of condensed tannins on Sephadex G-25 eluted with 50% aqueous acetone. J. Chromatog. 71:570.

Prescott, J. H. D., A. S. El-Shoboksky, and D. G. Armstrong. 1969. Ammonium salts of fatty acids for milk production. I. The effect of feeding a salt solution containing ammonium acetate on the yield and composition of milk produced by Jersey cows fed hay concentrate diets. Animal Prod. 11:195.

Owen, E. C., J. A. B. Smith, and N. C. Wright. 1943. Urea as a partial protein substitute in feeding of dairy cattle. Biochemical J. 37:44.

Repp, W. W., W. H. Hale, and W. Burroughs. 1955. The value of several nonprotein nitrogen compounds as substitutes in lamb fattening rations. J. Animal Sci. 14:901.

Rook, J. A. F., C. C. Balch, R. C. Campling, and L. J. Fisher. 1963. The utilization of acetic, propionic and butyric acids by growing heifers. Brit. J. Nutrition 17:399.

Rupel, I. W., G. Bohstedt, and E. B. Hart. 1943. The comparative value of urea and linseed meal for milk production. J. Dairy Sci. 26:647.

Santana, O. P. and J. T. Huber. 1970. Anhydrous ammonia treated corn silage for dairy cattle. J. Dairy Sci. 53:679.

Schuerch, C. 1963. The Hemicelluloses. In: The Chemistry of Wood. (B. L. Browning ed.), Interscience Publ., New York.

Seneca, H., J. K. Lattimer, P. Peer, and P. F. Stuart. 1961. Urease activity of sonic lysates of pathogenic bacteria. Lancet. 1:1166.

Seneca, H., J. K. Lattimer, and P. Peer. 1962. Bacterial urease in pathogenic bacteria. Arch. Pathol. 74:489.

Senel, S. H. and F. G. Owen. 1967. Relation of dietary acetic and butyric acids to intake, digestibility, lactation performance, and ruminal and blood levels of certain metabolites. J. Dairy Sci. 50:327.

Shaposhnikov, Y. K., L. V. Kosyukova, and Y. U. Vodzinskii. 1966. Gas chromatographic analysis of monohydric phenols. Gidrolizn. Lesokhim. Prom. 19(1):21:Chem. Abstracts 64:12939e.

Shaw, W. R. 1953. The inhibition of urease by various metal ions. J. Amer. Chem. Soc. 76:2160.

Staubus, J. R., R. F. Brown, C. L. Davis, and W. O. Nelson. 1958. Effects of acetate supplementation in calf feeding. J. Dairy Sci. 41:742 (Abstr.).

Streeter, C. L., R. R. Oltjen, L. L. Slyter, and W. N. Frishbein. 1969. Urea utilization in wethers receiving the urease inhibitor, acetohydroxamic acid. J. Animal Sci. 29:88.

Sumner, J. B. and G. F. Somers. 1953. Chemistry and Methods of Enzymes. 3rd ed. Academic Press, New York.

Thomas, J. W., L. A. Moore, M. Okamoto, and J. F. Sykes. 1961. A study of factors affecting rate of intake of heifers fed silage. J. Dairy Sci. 44:1471.

Thomson, R. H. 1964. Structure and reactivity of phenolic compounds. In: Biochemistry of Phenolic Compounds. (J. B. Harborne ed.) Academic Press: New York.

Timell, T. E. 1964. Wood hemicelluloses. In: Part I, Advances in Carbohydrate Chemistry 19:247.

Tsoumis, G. 1968. Wood As Raw Material. Pergamon Press: New York.

Van Buren, J. P. and W. B. Robinson. 1969. Formation of complexes between protein and tannic acid. Agr. Food Chem. 17:772.

Van Slyke, D. D. and G. E. Cullen. 1914. The mode of action of urease and of enzymes in general. J. Biol. Chem. 19:141.

Van Soest, P. J. and N. N. Allen. 1959. Studies on the relationships between rumen acids and fat metabolism of ruminants fed on restricted roughage diets. J. Dairy Sci. 42:1977.

Varner, L., W. Woods, and T. J. Klopfenstein. 1968. Urea or ammonium salts of volatile fatty acids as supplements to beef cattle rations. J. Animal Sci. 27:1773 (Abstr.).

Virtanen, A. I. 1975. Milk production of cows on protein-free feed. Special report to Masonite Corp., Chicago, Ill.

Wang, J. H. and D. A. Tarr. 1955. On the mechanism of urease action. J. Amer. Chem. Soc. 77:6205.

Watson, C. J., W. M. Davidson, and J. W. Kennedy. 1949. Nutrition value of nitrogenous compounds for ruminants. II. Formation of body protein from urea labeled with isotope N^{15}. Sci. Agr. 29:185.

Webb, D. W. 1971. Exogenous volatile fatty acid salts as energy sources and the nitrogen metabolism and ammonia toxicity of ammonium acetate in ruminants. Ph.D. dissertation, Kansas State University, Manhattan.

Wenzl, H. F. J. 1970. The Chemical Technology of Wood. Academic Press: New York.

Williams, D. L., J. D. Moore, L. C. Martin, and H. D. Tillman. 1975. Studies on liquid hemicellulose and cane molasses as carbohydrate sources in urea-containing diets of sheep. Special report to Masonite Corp., Chicago, Ill.

Wise, L. E. 1952. The hemicelluloses. In: Wood Chemistry (L. E. Wise and E. C. Jahn, ed.). Vol. 1. Rehinhold Publ. Corp.: New York.

Work, S. H. and L. A. Henke. 1939. The value of urea as a protein supplement replacement for dairy heifers. Proc. Amer. Soc. Animal Prod. 32:404.

Wyatt, M. J. 1965. The effects of intraruminal infusions of volatile fatty acids on food intake of sheep. New Zealand J. Agr. Res. 8:397.

Zelter, S. Z. and F. Leroy. 1966. Protection of dietary proteins against deamination by microorganisms. Z. Tierphysiol. Tierernahr, u Fullermittelkunde 22:39.

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APPENDIX

Table 1. Effect of Starea, Masonex, or cane molasses on urea degradation, ammonia release, gas production and microbial protein synthesis in vitro (6 h fermentation). 1975-1976.

Date	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Decrease in urea-N	Decrease in urea-N	Gas production (6 h)	Protein synthesized (6 h)
	mg N/100 ml						%	ml	mg
				Corn Starea					
(Oct. 30)	6.77	44.70	37.93	98.87	58.91	39.96	40.4	155.5	40.62
(Nov. 11)	6.09	79.52	73.43	116.66	101.71	14.95	12.8	146.5	37.68
(Nov. 18)	5.42	77.88	72.46	110.38	16.93	93.45	84.7	197.0	34.21
(Dec. 17)	6.77	35.89	29.12	150.34	123.35	27.09	18.0	131.0	17.34
(Dec. 30)	6.77	98.87	92.10	114.45	10.16	104.29	91.1	238.5	12.14
(Dec. 30)	6.09	69.75	63.66	106.33	35.22	71.11	66.9	260.0	12.14
(Feb. 10)	7.45	85.33	77.88	110.06	13.54	96.52	87.7	205.1	20.48
(Feb. 17)	6.86	92.10	82.62	100.90	0.00	10.90	100.0	293.3	21.30
Avg.	6.86	72.99	66.15	101.12	44.97	68.53	62.7	203.4	24.49

Table 1 (cont'd).

Date	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Decrease in urea-N	Decrease in urea-N	Gas production (6 h)	Protein synthesized (6 h)
	mg N/100 ml						%	ml	mg
				New Masonex (Oct. '75)					
(Dec. 17)	6.77	32.51	25.74	155.76	126.63	29.13	18.70	45.5	18.88
(Dec. 30)	5.42	52.14	46.72	160.49	107.00	53.49	33.30	65.5	15.69
(Dec. 30)	4.74	56.21	51.47	153.05	96.84	56.21	36.73	65.5	16.90
(Feb. 10)	7.45	65.01	57.56	134.76	70.43	64.33	47.70	87.5	21.40
(Feb. 10)	6.09	47.40	41.31	134.77	91.43	43.34	32.20	98.8	19.64
(Feb. 17)	6.09	91.42	85.33	138.15	41.31	96.84	70.10	144.0	11.46
(Feb. 17)	3.39	41.99	38.60	140.85	96.16	44.69	31.70	118.5	15.09
Avg.	5.71	55.25	49.54	145.40	89.26	55.43	38.60	89.3	17.01

Table 1 (cont'd).

Date	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Decrease in urea-N	Decrease in urea-N	Gas production (6 h)	Protein synthesized (6 h)
	mg N/100 ml						%	ml	mg
				Masonex (July '75)					
(Oct. 17)	10.84	25.06	14.22	163.20	127.99	35.21	21.6	64.0	20.99
(Oct. 21)	6.77	53.49	46.72	140.80	89.40	50.78	36.2	98.0	13.90
(Oct. 30)	6.09	37.92	31.83	148.31	111.74	36.57	24.7	101.0	13.09
(Nov. 11)	6.09	69.95	63.86	153.20	96.67	56.53	36.9	51.0	2.14
(Nov. 18)	4.06	53.50	49.44	153.05	89.39	63.66	41.6	53.0	7.49
(Dec. 17)	6.77	33.18	26.41	158.47	123.93	34.54	21.8	51.5	-
(Dec. 30)	5.42	49.44	44.02	162.53	103.61	58.92	36.3	65.0	17.70
(Dec. 30)	4.74	50.79	46.05	165.24	108.35	56.89	34.4	111.0	8.90
(Feb. 10)	8.13	86.00	77.87	145.59	46.05	99.54	68.4	90.3	18.53
(Feb. 10)	6.09	55.53	49.44	130.70	75.85	54.85	41.9	120.3	14.44
(Feb. 17)	6.77	106.32	99.55	136.12	31.83	104.29	76.6	122.5	14.76
(Feb. 17)	3.39	50.11	46.72	142.20	85.33	56.87	40.0	136.0	15.56
Avg.	6.33	55.94	47.18	149.90	90.85	59.05	40.0	88.7	13.41

Table 1 (cont'd).

Date	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Decrease in urea-N	Decrease in urea-N	Gas production (6 h)	Protein synthesized (6 h)
	mg N/100 ml						%	ml	mg
				Masonex (1969)					
(Dec. 17)	6.77	33.86	27.09	145.60	122.57	23.03	15.8	44.5	2.04
(Dec. 30)	6.09	67.04	60.95	162.53	86.01	76.52	47.1	75.0	5.90
(Dec. 30)	4.74	54.85	50.11	154.40	100.23	54.17	35.1	115.0	17.40
(Feb. 10)	8.13	86.68	78.55	144.24	52.15	92.09	63.8	72.8	9.56
(Feb. 10)	5.42	54.18	48.76	132.05	81.26	50.79	38.5	76.8	10.20
(Feb. 17)	6.09	95.49	89.44	137.48	43.34	94.14	68.5	90.5	6.75
(Feb. 17)	4.06	46.05	41.99	142.89	90.74	52.15	36.5	74.0	8.01
Avg.	5.90	62.59	56.69	145.60	82.33	63.70	43.6	78.4	8.55

Table 1 (cont'd).

Date	Initial NH_3-N	Final NH_3-N	Increase in NH_3-N	Initial urea-N	Final urea-N	Decrease in urea-N	Decrease in urea-N	Gas production (6 h)	Protein synthesized (6 h)
	mg N/100 ml						%	ml	mg
				Cane molasses					
(Sept. 9)	18.96	46.05	27.09	152.37	101.58	50.79	33.3	144.0	23.70
(Sept. 18)	13.54	74.49	60.95	134.77	78.56	56.21	41.7	190.0	-
(Oct. 17)	12.19	30.47	18.28	150.34	127.32	23.02	15.3	179.5	4.74
(Oct. 21)	6.77	59.59	52.52	127.32	81.94	45.38	35.6	146.0	12.11
(Oct. 30)	6.09	29.12	23.03	146.96	112.41	34.55	23.5	122.0	5.88
(Nov. 11)	4.74	69.95	65.21	161.17	143.80	17.37	10.8	158.0	25.85
(Nov. 18)	3.39	70.43	67.04	155.75	62.98	92.77	59.6	188.0	21.91
(Dec. 17)	7.45	46.05	38.60	158.46	103.61	54.85	34.6	130.0	12.50
(Dec. 30)	5.42	74.49	69.07	172.01	100.90	71.11	41.3	217.0	12.37
(Dec. 30)	4.06	67.04	62.98	155.76	83.30	72.46	46.5	222.5	15.58
Avg.	8.26	56.77	48.48	151.49	99.64	51.85	34.2	169.7	14.70

THE EFFICIENCY OF UTILIZATION OF THE EXOGENOUS AMMONIUM SALTS OF VOLATILE FATTY ACIDS AND HEMICELLULOSE EXTRACT IN RUMINANTS

by

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AN ABSTRACT OF A MASTER'S THESIS

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As the human demand for cereal grains increases, alternate sources must be found to supply the energy and protein needs of ruminant animals. One possible alternative is industrial products and byproducts. Volatile fatty acids and wood hemicellulose extract are two products of industrial processes which might be used as sources of feed for ruminant animals.

In Part I, the effects of feeding ammonium salts of volatile fatty acids (VFA) on intake, nutrient digestibility, and nitrogen balance were determined in a 12 wk feeding trial. A 3 x 3 Latin square design was used to compare a low protein (control) ration with rations supplemented with enough ammonium acetate or ammonium propionate to satisfy NRC requirements for protein for steer calves. The experimental animals were six Holstein steers weighing approximately 140 kg.

No decrease in intake was noted as a result of VFA supplementation. Average daily weight gains and feed efficiency were slightly greater (not statistically significant) for calves on the VFA supplemented rations than for calves on the control ration.

The intake of nitrogen was greater on the supplemented rations than on the control ration because of the added nitrogen in the ammonium form. A significant increase in the amount of nitrogen retained and a significant increase in the nitrogen retained as a percentage of intake for the VFA supplemented rations suggests that the supplemental nitrogen was absorbed and retained by the animal for use. Ammonium propionate showed a slightly greater value (not statistically significant) for nitrogen retained as a percentage absorbed than either control or ammonium acetate supplemented rations.

The addition of ammonium salts of VFA significantly improved dry matter digestibility over the control ration. Crude fiber digestibility was also improved by addition of the VFA salts but not significantly. The rations with ammonium salts significantly improved protein and energy digestibility over that of the control ration. This suggests that the additional nitrogen and energy from the VFA salts was utilized to biological advantage.

In Part II, a study was undertaken to determine the effects, in vitro, of Masonex, a hemicellulose extract from the Masonite Corporation, Chicago, on ruminal urease inhibition, ammonia release, and protein synthesis.

After 6 h fermentation in vitro the concentration of ammonia nitrogen in the Masonex and cane molasses samples was lower than for corn Starea. Ammonia nitrogen production increased with an increase in the age of Masonex, suggesting a possible breakdown of the urease inhibitory factor with age. The Masonex samples showed approximately 20% less urea degradation than the Starea. Masonex and cane molasses samples were significantly lower in microbial protein synthesis than Starea. There was also a significant difference in protein synthesis between new Masonex (Oct. '75) and older (3 mo and 6 yr old) Masonex samples. Urea utilization also increased with an increase in the age of Masonex.

Gas production, a measure of fermentability, was considerably lower for the Masonex samples than for cane molasses or Starea. The older Masonex sample was slightly less fermentable than the new samples.

Final pH is an indication of production of volatile fatty acids and was related to fermentability in this experiment. The Masonex samples had an average pH of 6.25 as compared to 4.79 for Starea and 5.3 for cane molasses, indicating a greater fermentation for Starea and cane molasses than for Masonex.

In a 9 h in vitro fermentation the urea utilization in the Masonex sample was just as extensive as in the Starea sample. The Masonex samples supported a greater total protein synthesis in 9 h than did the Starea. This is further indication of a loss of the urease inhibiting factor in Masonex after 6 h.