The effects of M-analog supplementation when fed pre and postpartum to range cows and ewes
by William Jon Langford

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Animal Science
Montana State University

Abstract:
Two studies of range cows and sheep, each lasting one year, were conducted at the Red Bluff Research Ranch of the Montana Agricultural Experiment Station. Purpose of the two part- experiments was to check the effects of feeding M-analog to range cows and sheep, determine the proper time to feed (pre or postpartum) and find the most beneficial level of supplementation. Forty-two cows selected at random, divided into three treatments: control (no M-analog) , two (10 g M-analog postpartum) and three M-analog (5 and 10 g M-analog pre and postpartum) were weighed and supplemented for 101 days. Data collected included cow: weights, gains, milk production and composition, calf weights and gains. Milking data revealed no significant effects due to calf sex or cow treatment. Calf ADG and weaning weight showed a significant($P<.05$) effect due to cow supplementation . Control cows reared 211.8 kgs. calves compared to 216.7 and 231.7 kgs. for treatment two and three cows, respectively. Ewes (57) randomly distributed over a similar feeding design revealed no effects due to M-analog supplementation on weights, gain, wool data, milk data, lamb(s) weight or gain. Type of birth and lamb rearing combination had significant ($P<.05$) effects on ewe weights on trial and weight loss during parturition. In 1 978,. 80 cows were fed four levels of elemental sulfur and M-analog. Cow treatment effect on milk showed a significant decrease in amount of milk collected at the 42±1 day milking. Cows fed 5 g of Mranalog per day milked 2.45 kgs per one half the udder as compared to 1.96 kgs. for cows fed 15 g of M-analog. -Control and 10 g fed cows produced 2.19 and 2.28 kgs, respectively. Calves on control and 5 g M-analog cows, 225.5 and 225.7 kgs were significantly ($P<.05$) heavier than 10 and 15 g treatment reared calves at 212.5 and 213.5 kgs by weaning (204 average days of age). Calf sex affected cow weights and losses ($P<.05$) and calf weights and gains ($P<.01$) for the 1977 and 1978 beef cow feeding trials. Ewes (127) which were divided into four random groups for a similar feeding trial showed treatment two ewes fed 1.25 g M-analog per day lost significantly ($P<.05$) less weight postpartum and produced the most milk .21 Kg. at the 35±1 day milking. However, ewes on 3.75 g M-analog weaned the heaviest and fastest gaining lambs on trial.

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William Jon Langford

This thesis has been read by each member of the thesis committee and found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

April 13 1983
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ABSTRACT

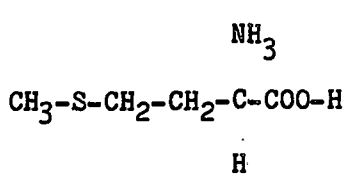
Two studies of range cows and sheep, each lasting one year, were conducted at the Red Bluff Research Ranch of the Montana Agricultural Experiment Station. Purpose of the two part experiments was to check the effects of feeding M-analog to range cows and sheep, determine the proper time to feed (pre or postpartum) and find the most beneficial level of supplementation. Forty-two cows selected at random, divided into three treatments: control (no M-analog) , two (10 g M-analog postpartum) and three M-analog (5 and 10 g M-analog pre and postpartum) were weighed and supplemented for 101 days. Data collected included cow: weights, gains, milk production and composition, calf weights and gains. Milking data revealed no significant effects due to calf sex or cow treatment. Calf ADG and weaning weight showed a significant($P<.05$) effect due to cow supplementation . Control cows reared 211.8 kgs. calves compared to 216.7 and 231.7 kgs. for treatment two and three cows, respectively. Ewes (57) randomly distributed over a similar feeding design revealed no effects due to M-analog supplementation on weights, gain, wool data, milk data, lamb(s) weight or gain. Type of birth and lamb rearing combination had significant ($P<.05$) effects on ewe weights on trial and weight loss during parturition. In 1978, 80 cows were fed four levels of elemental sulfur and M-analog. Cow treatment effect on milk showed a significant decrease in amount of milk collected at the 42 ± 1 day milking. Cows fed 5 g of M-analog per day milked 2.45 kgs per one half the udder as compared to 1.96 kgs. for cows fed 15 g of M-analog. Control and 10 g fed cows produced 2.19 and 2.28 kgs, respectively. Calves on control and 5 g M-analog cows, 225.5 and 225.7 kgs were significantly ($P<.05$) heavier than 10 and 15 g treatment reared calves at 212.5 and 213.5 kgs by weaning (204 average days of age). Calf sex affected cow weights and losses ($P<.05$) and calf weights and gains ($P<.01$) for the 1977 and 1978 beef cow feeding trials. Ewes (127) which were divided into four random groups for a similar feeding trial showed treatment two ewes fed 1.25 g M-analog per day lost significantly ($P<.05$) less weight postpartum and produced the most milk .21 Kg. at the 35 ± 1 day milking. However, ewes on 3.75 g M-analog weaned the heaviest and fastest gaining lambs on trial.

INTRODUCTION

Ranchers raising cattle or sheep strive to raise the heaviest calves or lambs possible under the existing conditions each year. Weight gains and weaning weights of both calves and lambs depend in part on the producing ability of the dam. Each dam must have proper nutrition to maintain maximum productivity. Complete rations meeting the nutritional requirements for production and maintenance of the dam are a necessity. A feed additive affecting the producing ability of the dam by increasing milk production levels, constituent levels of milk, or wool production could result in economic gain through increased weaning weights of the young or dam production.

Methionine Hydroxy Analog, M-analog, or hydroxymethionine have been shown to increase the producing ability of the dam (Varner 1974). M-analog is considered a natural feed substance formed as a salt of calcium. It is similar to the amino acid methionine, yet the structures of methionine and M-analog differ (Figure 1.)

Methionine:



M-analog:

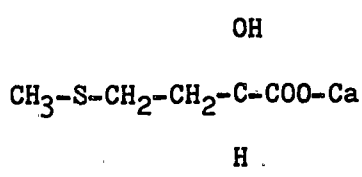


Figure 1. Chemical Structures of Methionine and M-analog.

M-analog research has been done primarily with dairy cows, because environments in dairy operations allow for closer and more frequent inspection of each cow's production. An alteration in milk quantity or quality because of nutritional or other factors can be determined, and changed when necessary.

Range cow and sheep operations are as varied as the individuals who manage them. After animals are turned out in the spring, it is difficult to assess how well each animal unit is doing until weaning. The rancher therefore attempts to give the cow and calf or ewe and lamb(s) the most advantageous start toward higher gains and weaning weights. How well a cow or ewe produces between parturition and weaning will have a direct bearing on the weights of the young at weaning. Production increased through supplemental feeding could therefore be useful in a ranch management plan.

In an attempt to alter postpartum productivity of range cows or sheep, supplemental feeding of M-analog was used in this study. Experiments assessing M-analog's effects were undertaken to determine the following:

1. The effects of feeding M-analog to range cows and ewes.
2. The best time to feed M-analog (pre or postpartum).
3. The most beneficial level of M-analog supplementation.

The following manuscript is a discussion of the nutritional aspects and results of M-analog supplementation.

LITERATURE REVIEW

McCarthy et al. (1968a) discovered alterations of lipoprotein fatty acid composition in the metabolically disturbed situation of ketosis and low fat test. McCarthy et al. (1968b) considered that this condition resulted from a deficiency of methionine.

The amino acid methionine has beeen shown to be effective in alleviation symptoms of bovine ketosis through intravenous administration (McCarthy et al. 1968b). It was believed that giving methionine would be unsuccessful due to ruminal microflora degradation. M-analog (Methionine Hydroxy Analog) was selected as a possible substitute for methionine in oral feeding to prevent bovine ketosis. Treatment of 42 dairy cows of four different breeds gave inconclusive results as none of the control treatment cows exhibited symptoms of the disease according to McCarthy et al. (1968b).

Milk production of the above mentioned cows during the eight weeks the cows consumed M-analog was monitored by Griel et al. (1968). Results of the milk monitoring showed 15 cows fed no M-analog produced on the average 87.9 kilograms (kgs) of 4% fat corrected milk (FCM) per week. Feeding M-analog at 40 grams and 80 grams per day to 14 and 13 cows respectively gave levels of 94.5 and 89.4 kgs. of fat corrected milk. Several explanations have been proposed for the increases in milk production.

1. Rumen microflora, while producing protein were unable to produce sufficient methionine; in other words, methionine may be a limiting amino acid. M-analogthus reduced a

possible methionine amino acid deficiency.

2. M-analog altered the rumen environment of the postruminal digestiblities, increasing the amount and/or availability of constituents required for milk production.
3. M-analog was a more readily available source of sulfur required by the cows.

Limiting Amino Acid

Methionine, an essential amino acid, serves as an important building block of proteins. Ruminant animals degrade amino acids into their various components to be resynthesized into protein by rumen microbes.

The quality of the microbial synthesized protein has been investigated. Ellis et al. (1959) used urea, gelatin and casein ration to check rumen microbes' ability to synthesize protein. Their findings indicated that the capacity of rumen microorganisms to synthesize trytophan, methionine, or lysine was insufficient. Abdo et al. (1964), in processing preparations of mixed ruminal bacteria and protozoa to be used as a monogastric diet, discovered high levels of tryptophan and lysine and limiting or low amounts of the sulfur containing amino acids.

The methionine plasma levels of cows fed a purified diet with urea as the only significant nitrogen source were only 67% of the value for normally fed cows (Virtanen 1966). Because normal feeding showed a low free methionine plasma level, the 33% decrease from normal to the purified nitrogen diet may be quite significant.

McDonald (1968) suggested that microbial and leaf protein would have a biological value of 75 on an amino acid basis when compared with whole egg protein at nearly 100, with amino acids containing sulfur again being the first limiting factors. Contrary to the above references, Schwab et al. (1975) deemed lysine followed by methionine as limiting in trials conducted on lactating dairy cows.

Abomasal infusion has been used to establish which amino acids, if any, are limiting in the ruminant animal. Nimrich et al. (1970), using urea as the sole source of nitrogen for growing lambs, tested by abomasal infusion the use of supplemental amino acids. Results of the qualitative assessment showed methionine to be the first limiting amino acid for the lambs on this trial. Similar results were achieved by Schelling et al. (1973) on growing sheep fed a high quality 11.6% protein diet. Comparison of methionine infusion and a combination of urea and sulfate at levels equal to the nitrogen and sulfur levels supplied by methionine led Schelling et al. (1973) to suggest methionine as a limiting amino acid.

Lysine was shown to result in 16% of the total response to amino acid supplementation with infusion (Schwab et al. 1976). Methionine infusion had no effect on secretion of milk, milk protein or fat concentration in the same experiment. A combination of lysine and methionine, however, accounted for 43% of the total response of amino acid supplementation. Thus Schwab et al. (1976) assumed lysine and methionine to be co-limiting.

Clark et al. (1978), by tracing amino acids uptake on cell cultures of mammary glands, discovered that threonine or methionine

improved Beta lactoglobulin synthesis and that cystine increased Beta casein. Beta lactoglobulin and beta casein are both milk proteins formed by the mammary gland cells. Clark et al. (1978) considered the limiting amino acids order for the synthesis of milk protein by mammary gland cells to be: cystine, threonine and then methionine.

Using a mixture of 13 amino acids, Reis and Tunks (1978) discovered that the omission of methionine from the 13 amino acid standard mixture inhibited wool growth rate. Both the fiber diameter and length of wool grown per day were reduced below those of the controls. These results agreed with experiments by Wright (1969). Both experiments show that the sulfur containing amino acids are specifically limiting for maximal wool growth.

M-analog vs. Methionine

References thus far have indicated methionine to be at least one of the three main limiting amino acids. M-analog replacement of methionine depends on the following:

1. Whether M-analog bypasses rumen degradation and replaces methionine post-ruminally.
2. Whether M-analog does have an affect in the rumen if rumen bypass cannot be accomplished.

Rumen Bypass

One of the first explanation of M-analog's effect was its structure. Enzymes of microorganisms responsible for methionine breakdown may not recognize and act upon the analog of methionine. This would allow M-analog to pass into the abomasum where either

absorption of M-analog or conversion to methionine could take place. Benefits from M-analog supplementation thus might be possible if M-analog and methionine were interchangeable in the free amino acid plasma pool.

Gosset et al. (1962) assumed M-analog did not function or perform well as DL-methionine. This assumption was based on findings of no benefit to gains or feed efficiencies at 5 grams of M-analog per head per day of steers fed high urea content fattening rations.

Wright (1969), using sheep, reported significant increases in the wool growth rates of lambs fed either 8% or 12% protein rations with 0.3% methionine or M-analog making up part of the total diet. Unlike Gosset et al. (1962), Wright (1969) believed this improved growth indicated that both methionine and M-analog may have been effective in the rumen or postrumimally.

Reis (1970), using orally administered amounts of M-analog to wethers at 0, 2, 4, and 8 grams per day, indicated that at the dosages given the M-analog did not influence wool growth, as seen by the corresponding wool growth rated of 108%, 113%, 107% and 115%. Because the wool growth rate percentages did not follow the effects of abomasal infusion of M-analog, Reis (1970) felt degradation of M-analog had occurred in the rumen.

Belasco (1970) conducted research on the stability of M-analog in rumen fluid. M-analog proved to be more resistant than L-methionine to rumen degradation. Thus, M-analog would be in a higher concentration postruminally than the same amount of methionine if both were fed orally.

Langland (1972) fed 2.69 grams of M-analog per day to penned sheep, increasing wool production 15%. Abomasal infusion of the same amount of M-analog increased growth of wool 32%. Experiments with grazing sheep being fed 3.9 grams M-analog per head per day showed a 35% increase in wool production. These experiments may indicate that rumen bypass of M-analog is not 100%. The difference between wool growth in oral and abomasal feeding of the same amount of M-analog produced a 17% difference in wool growth.

Papas et al. (1974) orally administered to lambs 3.08 grams of M-analog and 2.7 grams of DL-methionine (equivalent amounts of both active ingredients) in an attempt to increase the plasma methionine:valine ratio. Neither treatment was effective in increasing the methionine:valine plasma level above that of the controls, indicating that neither DL-methionine or M-analog may undergo rumen bypass.

Postruminal Effect of M-analog and Methionine

If some portion of the orally fed M-analog was unaffected in the rumen, what effect could it have postruminally if absorbed through the gastrointestinal system?

An *in vitro* experiment by Belasco (1972) revealed that microsomal fraction enzyme systems of calf kidney and liver were capable of converting M-analog to methionine, indicating that once absorbed, M-analog could take the place or be used in place of methionine.

However, Papas et al. (1974) felt it unlikely that M-analog would support the postruminal requirements for methionine. The plasma

methionine:valine ratios indicated that less than one-third of the abomasally infused M-analog was converted to methionine. The plasma methionine:valine ratio was significantly less for control lambs fed either M-analog or DL-methionine. Lambs fed M-analog still had ratios significantly less than lambs infused with DL-methionine.

In preruminant lambs, Walker and Kick (1975) concluded that the D and L isomers of methionine had similar biological activity when used to supplement isolated soya protein and that M-analog was effective as DL-methionine. However, Miller and Rodriquez (1975) showed reduced gains, intake and serum amino acids, possible due to an amino acid imbalance when M-analog was given to 36-three day old Holstein calves.

In nonruminants, M-analog was found to have a 70.1% activity on a feed efficiency basis for broilers (Harms et al. 1976). Chow and Walser (1975) using rats, felt that the ability of M-analog to replace methionine was complete.

The only sure way devised to study the effect of methionine of M-analog without rumen degradation is through infusing the desired amount of either into the abomasum of the ruminant animal. Sheep are used in this capacity because of handling and sampling ease of wool growth.

Methionine infusion at 2.46 grams per day increased wool growth from 35 to 150% over a 6 week period for Reis and Schinckel (1963). Wool growth was again increased by 123 to 181% in experiments conducted by Reis and Schinckel (1964) using the infusion of 60 grams of casein per day for 9 weeks. An increase of 16 to 37% in wool growth over the casein diet was obtained by the addition of sulfur

containing amino acids to the casein upon infusion. A comparison of DL-methionine at 2.46 grams per day increased wool growth by an average of 80%. A 78% increase was observed when 3 grams of M- analog were given per abomasum with a 37% recovery of supplemented sulfur found in the wool. Similarly, Reis (1970) doubled the wool growth rate using 3 grams of M-analog through abomasal infusion.

The references listed above seem to indicate that introduction of M-analog into the postruminal digestion may be of benefit, at least in wool growth. Methionine seems more consistent in causing increased wool growth, yet increases caused by M-analog and methionine are very similar when both were administered through abomasal infusion.

M-analog's Effect on the Rumen

Consideration of M-analog's action has also centered around the possibility that M-analog does not undergo rumen degradation and is bypassed to the abomasum. Evidence contrary to rumen bypass has also been cited. If this evidence is true, the question of M-analog's effect on the rumen environment requires exploration to find the full extent of M-analog supplementation. A large fermenting vat, the rumen acts not only as a manufacturing site for protein, lipid and/or volatile fatty acids, synthesized by bacteria and protozoa, but also as a site of absorption of these products.

Rumen Amino Acids and M-analog Absorption

Cook et al. (1965) determined that absorption of amino acids did occur through the rumen wall. Inserting polyethelene catheters into the right ruminal veins of 3 ruminant animals allowed measurement of

amino acid levels of blood from the rumen before, during and after amino acid supplementation. Analysis of the blood samples showed that no methionine was absorbed, but an altered form methionine sulfoxide was found. Thus, methionine activity is possible through rumen absorption, if methionine sulfoxide has the ability to take methionine's place in the blood amino acid plasma pool.

Unlike Cook et al. (1965), Whiting et al. (1972) showed M-analog supplementation at .22% of the basal diet of cubed alfalfa with a pelleted concentrate increased the rumen content of threonine and not that of methionine.

M-analog fed at .3, .8 and 1.2% of a 10% hay and 90% concentrate diet by DeVuyst et al. (1976) resulted in each level giving a considereable rise in the total methionine concentration of the rumen. The amounts of amino acids in the blood stream are very small. Any increase in methionine activity through supplement of M-analog in which there are significantly increased amounts of methionine sulfoxide in the rumen outflow blood may be beneficial to the ruminant animal.

M-analog and Rumen Protein Synthesis

It is well documented that bacterial and protozoal protein synthesis occurs in the rumen. Kahlon et al. (1975a) tested 6 different chemical sources of sulfur for their effect on *in vitro* rumen protein synthesis. The six sources of sulfur were L-methionine, calcium sulfate, sodium sulfate, elemental sulfur, M-analog and a control with no additional sulfur added. The rumen inoculum was

tested at various incubation times of 0, 6, 12 and 18 hours. Protein synthesis observed with M-analog was significantly lower than that with any other source at 12 hours of incubation. The effectiveness of M-analog over the whole 18 hours trial ranked no higher than third compared to all sulfur sources. Only the control averaged lower in stimulation of protein synthesis. Kahlon et al. (1975a) continued by checking the *in vitro* protein synthesis availability of these same sulfur sources plus DL-methionine and ammonium sulfate. L-methionine exhibited the highest sulfur source availability at 100%. M-analog's availability was only 28.8%, the lowest of all the sulfur sources tested.

Rumen Microflora and M-analog

Aside from protein synthesis, the rumen has many other functions. Rumen microorganisms, bacteria and protozoa are used by the ruminant animal, and alterations in amounts or quality may have an effect on the animal's production. M-analog's effect, if any, may be beneficial to rumen microflora.

Protozoa

Rumen protozoa, bacteria and brewer yeast, when fed to rats as a protein source, revealed biological values for protein of 80, 81 and 72%. Coresponding values for the digestibilities were 81, 74 and 84%, respectively (McNaught et al. 1954). A comparison of the biological value with the digestibility suggests that the conversion of bacterial or dietary protein into protozoal protein in the rumen would be advantageous to the host animal. Further, studies on protozoa by

Yoder et al. (1966) demonstrated that the addition of washed rumen protozoa increased the cellulose digestion by *in vitro* bacterial cultures. The cellulose breakdown was in the presence of added volatile fatty acids, vitamin B_{12}, biotin and hydrolyzed casein.

Patton et al. (1970) discovered rumen protozoa concentrations significantly higher in sheep fed a grain plus M-analog diet than in sheep receiving only grain. However, for sheep fed grain plus M-analog, protozoa levels were significantly lower than those of sheep fed hay and grain. Samples showed protozoal concentrations of 6.0 X 10^6 protozoa as compared to 5.0 X 10^6 protozoa per milliliter of rumen fluid in cows receiving 80 grams or 0 grams of M-analog.

Levels of M-analog were used by DeVeryst et al. (1976) at .3, .8 and 1.2% of the diet on rumen fistulated sheep. The .8% level showed marked increase in the total number of ciliate protozoa found in the rumen. No further increase was obtained with the 1.2% M-analog diet. From the evidence cited above, there is a possible advantage to be gained through alteration of the bacteria to protozoa ratio.

Bacteria

Cellulose digestion depends on the production of enzymes by bacteria which are able to breakdown Beta 1-4 glucose linkages, the primary constituent of cellulose. Altered cellulose digestibility could mean activation or inhibition of bacteria because of M-analog.

The addition of 4 grams of M-analog per 100 milliliters of rumen bacteria and fluid increased cellulose digestion by 6 and 5% at 24 and 48 hours of incubation in *in vitro* studies by Gil and Shirley (1972).

Experiments found M-analog to be more effective at 24 hours of incubation, but no difference between sodium sulfate and M-analog was observed at 48 hours of incubation on cellulose digestion. A highly significant difference was also found in the bacterial nitrogen levels. Values were .26 milligrams nitrogen per milliliter of rumen fluid with M-analog and .16 milligrams without M-analog.

Bull and Vandersall (1973) used sodium sulfate, calcium sulfate, DL-methionine and M-analog as sulfur sources. Bacterial cellulose digestiblity was comparable among all forms of sulfur, with no significant alterations from M-analog in in vitro trials. However, Gil et al. (1973) again demonstrated that both methionine and M-analog accelerated bacterial nitrogen incorporation when cellulose or glucose was used along with urea as a nitrogen source.

Rumen Lipids

Alterations of the rumen environment with respect to rumen lipids or volatile fatty acids can also play major roles in the production picture of the ruminant animal.

A marked stimulation in lipid synthesis, approximately 63.6% greater than control rations, regardless of the total quantity of lipid present in the rumen fluid sample, was seen with in vitro addition of methionine (Patton et al. 1968). Tracer studies using acetate, glucose and long chain fatty acids revealed that methionine produced substantial transfer of carbon from these sources to complex microbial lipid associated with rumen protozoa (Patton et al. 1970). Patton et al. (1970) used rations with 0, 40 and 80 grams of M-analog

over an eight week trial period. Rumen lipid levels were tested at weeks 1, 3 and 8. Results were measured in milligrams per 75 milliliters of rumen fluid. All three diets resulted in decreases, yet decreases seen in M-analog diets were much larger. Blood lipid levels were increasing during the same interval with the M-analog diet. Highly significant increases of rumen volatile fatty acid production were observed with M-analog used in <u>in vitro</u> studies conducted by Gil and Shirley (1972). Contrary to the above, Whiting et al. (1973) showed no effects by M-analog on rumen volatile fatty acids levels. However, their measurement of volatile fatty acids was by the accumulation of serum cholesterol in the blood and not serum lipid levels.

Volatile fatty acid levels greatly influenced the amount of fat found in milk in the ruminant animal. Significant rumen increases in propionic acid levels were followed by decreases in blood ketone bodies and milk fat. Feeding sodium acetate increased milk fat, whereas feeding sodium propionate further decreased milk fat (Van Soest and Allen, 1959). In two trials conducted by Emery et al. (1964), sodium bicarbonate increased milk fat .81 and .86% units. The treatment effect, at least 40 to 69% was explained by the acetic to proprionic acid ratio established in the rumen. However, Davis (1967) concluded that an absolute shortage of acetate due to decreased rumen production is not responsible for the depression of the fat content of milk when a low fiber-high grain diet was fed.

M-analog's roles may be the enhancement of triglyceride transport into the mammary gland, as suggested by Rosser et al. (1971). This

conclusion was reached by checking triglyceride levels of arterial versus venous blood of the mammary gland of cows fed M-analog. This ration increased ruminal amounts of acetate and butyrate while decreasing proprionate. The increase in acetate with reduced proprionate may help to explain the reason for possible increase in milk fat while feeding M-analog. As both Van Soest and Allen (1950) and Emery et al. (1964) suggest the alteration of milk fat is due to the ratio of acetic to proprionic volatile fatty acids in the rumen.

However, alteration of the volatile fatty acids though M-analog supplementation may not affect the various lipid levels in the bloodstream of the ruminant. Fuquay et al. (1975) tested blood samples from cows fed 24 grams of M-analog per day for 80 days. No lipid classes were altered, leading to a conclusion of no M-analog effect.

Overall Digestion Effects

Rumen digestion is only a part of the overall digestion of the ruminant animal. Alteration of postruminal digestibilities must also be considered in forming a complete picture of all the possible actions of M-analog.

M-analog's effect on the total digestibility was considered nil by Whiting et al. (1972), because feeding of M-analog with cubed alfalfa and pelleted concentrate had no significant effect on digestibility of protein, fiber, fat or total feed. Bouchard and Conrad (1973) and Kahlon et al. (1975a) obtained similar results.

In contrast, Bull and Vandersall (1973) discovered significantly

greater dry matter and acid detergent fiber digestibilities with M-analog. The dry matter digestibility was greater for M-analog than for DL-methionine, sodium sulfate and the control ration. The acid detergent fiber digestibility was sigificantly higher for M-analog, but similar to that of DL-methionine, and sodium sulfate, when all were compared to a control ration. Bharagans et al. (1977) showed that daily fiber intake was higher for cows supplemented with .3% M-analog, from -1.6 kgs for control to 2.2 kgs with M-analog. Twenty-eight Holstein cows were divided into four treatments to compare unpelleted and pelleted rations (Polan et al., 1970). M-analog was added to one pelleted and one unpelleted ration. The pelleted ration demonstrated that M-analog was associated with a marked increase in digestibility of crude fiber, dry matter, the ether extract fraction, and improved nitrogen retention of the cows. Holter et al. (1972) fed cows two weeks prepartum to 24 weeks postpartum, and results indicated M-analog increased digestibilities of the fiber and fat portion of the ration.

M-analog and Sulfur Supplementation

Some researchers have felt that the beneficial effect of supplementation of M-analog are due to its sulfur content. A more available source of sulfur may have been presented to the ruminant animal by feeding M-analog. This sulfur source could improve digestibility, sulfur retention, nitrogen retention, or even feed intake if the animals were in need of more sulfur.

Reference to sulfur supplementation should include the National

Research Council (NRC) recommendation. In 1975 the NRC recommended 0.14 to .18% sulfur in the diet on a dry matter basis for mature ewes. Beef cattle recommendations are vague. It is recommended that 3 grams of sulfur be given for each 100 grams of nonprotein nitrogen. The recommendation drops to .10% of diet on a dry matter content.

Whiting et al. (1954) used six lots of mature range ewes fed sulfur in the form of methionine, inorganic sulfate and elemental sulfur. Treatment ewes were fed sulfur levels for eight months. Wool growth and quality, lamb production, ewe weight gain, sulfur serum content and sulfur milk content were measured, with no significant differences among the various forms of sulfur used in the experiment. Whiting et al. (1954) indicated that the sulfur requirement of mature range ewes did not exceed .10% of the total diet.

Jacobson et al. (1967) divided 24 lactating Holstein cows into two equal groups. The low sulfur group was given a supplement containing 10% sulfur. The sulfur supplemented group was given the same diet plus sodium sulfate. No significant differences were detected among treatments in any of the amino acid contents for either deproteinized blood plasma or hydrolyzed rumenm samples taken from cows 3 to 5 hours after feeding. Data collected indicated the sulfur supplemented group of cows failed to maintain the free plasma and rumen amino acid levels. Jacobson et al. (1967) felt the quality of sulfur was ineffective or the quantity insufficient to maintain the levels over the 9 week period.

Bouchard and Conrad (1973) fed M-analog, sodium sulfate and a mixture of potassium and magnesium sulfates, attempting to evaluate

their use as sulfur sources for lactating dairy cows. Ration containg 0.10, .15 and .18% sulfur were made using the basal diet sulfur content (.10% sulfur) plus sodium sulfate to make rations of .15 and 0.18% sulfur, respectively. A fourth ration was made by adding enough M-analog to the basal diet to bring the sulfur content to .18%. Sulfur supplementation of the basal diet increased the dry matter intake and dry matter digestibility. Sodium sulfate and M-analog both improved the sulfur balance of the lactating cows with supplements of 0.15 and .18% sulfur in the complete ration.

In vitro experiments conducted by Kahlon et al. (1975a) observed the availability of sulfur from various sources measured by in vitro protein synthesis. M-analog exhibited a lower availability than DL-methionine, calcium sulfate and even elemental sulfur. Unlike the in vitro experiment results which showed M-analog to be the lowest in sulfur availability, only 28.8% was as available as L-methionine sulfur. Kahlon et al. (1975b) in vivo studies showed that lambs fed M-analog had sulfur retention, sulfur intake and sulfur digestibility levels equal to or greater than those fed any other sulfur source, including DL-methionine.

M-analog and Production

Production of the ruminant animal varies with species. Sheep production is measured in amount of wool produced and lambs weaned. Dairy cattle have much different production measurements. Large quantities of high quality milk is the major criteria of production evaluation, along with reproductive performance. Beef cows have two

parameters of measurement: weaning the heaviest calf possible and returing to estrus for the following breeding season as soon as possible. M-analog research has been conducted on each species, with major emphasis on dairy cattle.

Dairy Cattle

M-analog, first used to experimentally treat ketosis in dairy cows by McCarthy et al. (1969b), was discovered to improve milk production (Griel et al., 1968). Milk production and butterfat content have been observed with positive effects on both parameters of production by Polan et al. (1971), Bishop (1971), Fosgate et al. (1973). Increases in butterfat content of milk with M-analog supplementation, but no substantiated increases in milk production were illustrated by Van Horn et al. (1975) and Bharagans et al. (1977). Experiments in which M-analog did not improve milk production or butterfat content of milk in dairy cows have been reported by Burgos and Olson (1970), Hutjens and Schultz (1971), Whiting et al. (1972), Bouchard and Conrad (1973), Fuquay et al. (1974), Olson and Grubaugh (1974) and Williams and Whithurd (1975).

Fuquay et al. (1975) examined M-analog's effect on the reproductive performance of dairy cows. A comparison of the M-analog to control diet shows a reduction in the number of days to first estrus from 45.8 days for control cows to 38.6 days for M-analog treated cows. Days to conception were reduced from 135.4 to 115.1, with number of services to conception decreased from 3.03 to 1.72. Similar data collected by Chandler et al. (1976) indicated that dairy

cows on control diets required 2.9 services per conception and were open an average of 156 days. Supplementation of M-analog at .125% of the diet to treatment cows cut service to conception ratios to 1.8 to 2.2 services and days open were reduced to the 124 to 134 day range.

Beef Cattle

Literature on beef cattle fed M-analog for fatten indicates reduced palatability (Sather et al., 1975, and Johnson and Totusek, 1976), no benefits to gains or feed efficiencies (Gosset et al., 1972, and Thomas and Langford, 1977), and even depression of gain performance when urea was fed to early weaned calves (Winter, 1976).

In the lactating beef cow, results have been similar to those in dairy cattle. Varner (1974) used 78 straight bred Hereford cows divided into three treatment groups: Control cows fed 0 grams, cows fed 5 grams, and cows fed 15 grams M-analog per day. Cows were fed from about 30 days before predicted calving date until an average of 60 days after calving. There was a significant increase in butterfat, milk production and 4% FMC for cows fed the 15 grams of M-analog per day. Weaning weights and adjusted 205 day weights for calves from the same cows were significantly greater than those of cows on the control ration.

In contrast, Varner et al. (1975) found no differences in treatments using 0 and 10 grams of M-analog per day from 30 days before the predicted calving date until 60 days after calving.

Reproductive performance was altered by M-analog supplementation. Varner (1974) decreased the postpartum period from 48.5 days with no