ANNUAL RESEARCH PROGRESS REPORT
Report of Progress (AD-421)

Accession: 0400174 Year: 98 Project Number: 1265-31000-063-00 D
Mode Code: 1265-50-00 STP Codes: 3.1.4.2 100%
NATL PROG(S) 102 Animal Production Systems 100%

Title: NUTRITIONAL AND PHYSIOLOGICAL FACTORS AFFECTING SPLANCHNIC ENERGY METABOLISM IN RUMINANTS

Period Covered From: 01/98 To: 12/98

Progress and Outcomes:

1. What major problem or issue is being resolved and how are you resolving it?

A complete feeding program requires a comprehensive understanding of not only the feed composition, but also an understanding of the animals' ability to use the feed for productive purposes. A large portion of the absorbed nutrients from the ruminant gut are modified or used, during microbial fermentation in the foregut and also by the absorptive tissues of the animal, prior to their release into the circulation. This results in a decrease in the supply of energy and amino acid precursors from a given feed source that is available to the productive tissues (muscle, adipose and mammary) of the animal. While this energy use cannot be considered a loss to the animal, the absorptive gut tissues perform a vital service to the productive tissues of the animal, it does represent a decrease in productive efficiency per unit feed energy supplied. Through the study of the nutrient metabolism of the absorptive tissues of the ruminant gut, a more complete understanding of how feed composition alters productive processes will be established. Since variation in gut size significantly affects net utilization of nutrients and ultimately total animal energy expenditure, it is vital to develop an understanding of the dynamics of cell growth and differentiation in addition to the study of gut tissue metabolism. Thus, a quantitative understanding of tissue metabolite use cannot be complete without comprehension of both metabolic capacities of cells and total multiplicity of the processes in vivo.

2. How serious is the problem? Why does it matter?

The gut and liver tissues of ruminants account for 30 to 50% of whole

body energy use, while representing only 8 to 10% of the total body mass. Thus, without an understanding of the dynamics of visceral nutrient use, improvements in the current models for animal feeding can not be made. The potential improvements include, but are not limited to, increasing the nutrients available to the animal's productive tissues, decreasing the excretion of excess nutrients due to improperly balanced diets, and decreasing costs of feeding due to a better formulation of diets. Feeding is the primary cost of both dairy and beef production and thus, savings in this area are crucial to successful animal production. In fact a nominal 2% increase in energetic efficiency would save the

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Beef and Dairy industries $200 million per annum in feed costs. Additionally, with the increasing concern related to the impact of animals on environmental health, it is becoming increasingly important to minimize lost nutrients and manage better the nutrients offered to the animal. This can not be accomplished without the development of better and more complete feeding paradigms.

3. How does it relate to the National Program(s) and National Program Component(s) to which it has been assigned?

This research addresses Objective 3 of the Agricultural Research Service Program 6 Year Plan: "Develop the means for increasing the productivity of animals and the quality of animal products"; Approach 3.1 "Improve the production efficiency of animals and quality of animal products"; and Approach Element 3.1.4-Nutrition "Improve animal nutrition and feed use to increase production efficiency" Through the study of the nutrient metabolism of the absorptive tissues of the ruminant gut, a more complete understanding of how feed composition alters productive processes will be established. We are looking to make improvements in the current models for animal feeding. The potential improvements include increasing the nutrients available to the animal's productive tissues, decreasing the excretion of excess nutrients due to improperly balanced diets, and decreasing costs of feeding due to a better formulation of diets.

4. What was your most significant accomplishment this past year?

Subtherapeutic levels of oral antibiotics enhance feedlot performance (i.e. rate and efficiency of growth) in beef cattle. However, the mechanism(s) by which these compounds alter performance has not been delineated. It has been generally hypothesized that the site of action of antimicrobial compounds is the gastrointestinal tract. This is based, at least in part, on studies which have shown that antimicrobial compounds reduced gut mass in swine. Thus, considering that the gut is highly metabolically active and has a rapid turnover rate, it seems reasonable that a reduction in gut mass would increase the supply of

metabolizable energy and essential amino acids to peripheral tissues for lean growth. Furthermore, recent data suggest that antimicrobial compounds increase circulating Insulin-like growth factor-I concentrations in swine. While this response would be consistent with a protein sparing effect, a direct effect of the hormonal axis can not be eliminated. Therefore, an experiment was conducted in steers to determine the effects of Aureomyicin and dietary protein level (10% vs. 13% CP) on the rate and efficiency of growth, circulating hormones, and visceral tissue mass, morphology and proliferation. Dietary protein had a positive effect on efficiency of gain while CTC had little effect on

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feed lot performance. During the initial 28 d of the study CTC increased IGF-I concentrations in steers fed the 10% CP, but did not those fed 13% CP. Oral administration of CTC decreased releasing hormone induced pituitary secretion of growth hormone and thyroid stimulating hormone after 56 d via a reduction in pituitary Type II deiodinase activity. Stomach complex was increased with dietary protein level, while oral administration of CTC decreased small intestinal mass. Tissue sections from these tissues are currently being analyzed for RNA, DNA, and protein content and determination of morphological changes and proliferative indices. Results from this study will aid in identifying the mechanism by which antimicrobial compounds improve productive efficiency. Furthermore, if these findings implicate changes in visceral mass and or cell proliferation as the primary mechanism for the observed increases in efficiency, this approach may serve as an important model for studying the relationship between perturbations in visceral tissue mass and energy metabolism in the whole animal.

5. Describe your major accomplishments over the life of the project, including their predicted or actual impact

Earlier studies conducted by this laboratory have shown that alterations in dietary energy density (i.e. concentrate vs. forage) and metabolizable energy intake affect splanchnic oxygen use as a percentage of whole animal oxygen use. Therefore, a study was conducted to determine if these changes could be explained by either an increase in splanchnic organ mass or mass specific changes in metabolism. Pelleted diets differing in energy density (ie. forage to concentrate ratio) were fed at two levels of metabolizable energy intake per kilogram of body weight to lambs for 49 days. An inverse relationship was observed between diet energy density and visceral mass while a positive relationship was largely observed between metabolizable energy intake and visceral and liver mass. The observed increase in mass of the stomach complex and intestines was a result of hyperplastic growth. Rates of oxidative metabolism by ruminal and duodenal epithelial cells were not influenced by dietary energy density or metabolizable energy

intake. Based on these data it can be concluded that the increase in visceral oxygen use associated with energy density and metabolizable energy intake can largely be attributed to changes in visceral tissue mass. These results further the understanding of the mechanisms controlling visceral organ growth and provide important data for the development of more complete models for the prediction of feed energy values for tissue growth and milk production.

As much as 80% of the dietary energy supplied to the high producing ruminant enters the portal system by crossing the rumen epithelium. However, the impact of diet and metabolizable energy intake on the

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metabolic fate of nutrients is largely undefined. An experiment was conducted using rumen epithelial cells isolated from lambs fed either concentrate or forage based diets at two levels of metabolizable energy intake. Unique kinetic parameter estimates were developed for the oxidative metabolism of the primary oxidative substrates used by the ruminal epithelium. These data demonstrated that the degree to which nutrients are metabolized are substrate dependent and that the oxidation of ruminal volatile fatty acids would be expected to operate at maximal rates under normal ruminal concentrations. Thus, only subtle changes in overall oxidative capacity in response to altered ruminal environment were noted. These novel parameter estimates provide essential data for the development of more complete and accurate prediction models which are central to improving the energetic efficiency of tissue growth and milk production.

Subtherapeutic levels of oral antibiotics enhance feedlot performance (i.e. rate and efficiency of growth) in beef cattle. However, the mechanism(s) by which these compounds alter performance has not been delineated. It has been generally hypothesized that the site of action of antimicrobial compounds is the gastrointestinal tract. This is based, at least in part, on studies which have shown that antimicrobial compounds reduced gut mass in swine. Thus, considering that the gut is highly metabolically active and has a rapid turnover rate, it seems reasonable that a reduction in gut mass would increase the supply of metabolizable energy and essential amino acids to peripheral tissues for lean growth. Furthermore, recent data suggest that antimicrobial compounds increase circulating Insulin-like growth factor-I concentrations in swine. While this response would be consistent with a protein sparing effect, a direct effect of the hormonal axis can not be eliminated. Therefore, an experiment was conducted in steers to determine the effects of Aureomyicin and dietary protein level (10% vs. 13% CP) on the rate and efficiency of growth, circulating hormones, and visceral tissue mass, morphology and proliferation. Dietary protein had a positive effect on efficiency of gain while CTC had little effect on feed lot performance. During the initial 28 d of the study CTC increased IGF-I concentrations in steers fed the 10% CP, but did not those fed 13%

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mass and or cell proliferation as the primary mechanism for the observed increases in efficiency, this approach may serve as an important model for studying the relationship between perturbations in visceral tissue mass and energy metabolism in the whole animal.

Development of the rumen is incomplete in the newborn ruminant. Development of the rumen does not commence until a viable ruminal fermentation is established. A study was conducted to evaluate the effect of volatile fatty acids and energy intake on sheep gastrointestinal development. As expected, feeding resulted in significant increases in ruminal size and development while, VFA infusion did not induce rumen development. However, mass of intestinal tissue segments were increased by both feeding and volatile fatty acid treatment. Thus, although VFA treatment at this dose is insufficient to induce normal ruminal development, intestinal development is stimulated by oral VFA infusion in developing lambs. These findings are fundamental to a better understanding of the mechanisms which regulate rumen growth and development and will lead to further investigations directed at determining the role of specific nutrients in regulating intestinal mass in ruminants.

The rumen epithelium increases in size and surface area in response to increased energy intake, presumably due to increased epithelial cell proliferation. Isolated ruminal cells were cultured in vitro to determine the effect of various growth factors on ruminal cell proliferation. Results showed that although butyrate has been implicated as a possible mediator of ruminal cell growth in vivo, growth factors such as insulin, insulin-like growth factor-I, and epidermal growth factor are more effective inducers of growth in vitro. However, butyrate altered the sensitivity of the cultured cells to the growth factors which resulted in a lower concentration of growth factor required to elicit the growth response. It can be inferred from these results that butyrate may indirectly affect rumen epithelial cell growth by changing the cellular response to growth factors. These findings provide insight into the relationship between fermentation end products and physiological responses and may ultimately lead to the development of new dietary regimens which improve rumen epithelial health and animal

performance.
Ketogenesis by the rumen epithelium accounts for a majority of the circulating ketone bodies in the fed ruminant. Research in vivo has demonstrated that ketogenesis by the rumen epithelium is altered by dietary inputs and changes in the ruminal environment. An experiment was conducted to evaluate the effects of volatile fatty acids on butyrate oxidation to ketone bodies using an isolated rumen epithelial cell system. Butyrate oxidation to beta-hydroxybutyrate was increased when propionate was included in the incubation medium. However, with increasing propionate the production of acetoacetate was decreased

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proportionally and thus, total ketone production by the cells was unaffected by propionate addition. The mechanism responsible for this alteration in the ratio of beta-hydroxybutyrate to acetoacetate appears to be that the ruminal cell metabolizes propionate to lactate which results in a net change the redox state of the mitochondria, thus favoring the production of beta-hydroxybutyrate over acetoacetate. These findings can be interpreted to indicate that changes in the ruminal environment can impact rumen epithelial cell metabolism.

Glucose is supplied to the dairy cow by both liver production from propionate (i.e. gluconeogenesis) and from dietary starch bypassing the rumen and subsequent absorption of glucose from the intestines. Because glucose is also required for milk production and is the precursor to milk lactose there is a need to know the effect of altering site of starch digestion on glucose supply and milk production. Site of starch digestion was altered directly by infusing 1500 g/day starch into either the rumen or abomasum of early lactation Holstein cows. Whole body supply of glucose, measured using isotopically labeled glucose infused intravenously, increased for abomasal but not ruminal infusion of starch. However, milk production was significantly increased with both abomasal and ruminal infusion of starch. This is unique information for dairy cows producing over 40 kg/day milk. Diets for high producing dairy cows will require inclusion of starch sources that optimize both ruminally degraded and ruminally undegraded starch.

The large summary of information derived from the Beltsville indirect respiration calorimeters for the past 30 years became the basis for the Net Energy for Lactation system for expressing energy requirements of dairy cattle in the US and in the world. This system was reported in the National Academy of Sciences, National Research Council's publication on nutrient requirements of dairy cattle. A data file of all calorimetry trials conducted in the Energy Metabolism Unit was compiled and transformed for use on a personal computer. Trials were filed according to animal type, animal production, and source and form of dietary ingredient. Two major data summaries were published from these trials. First, data were summarized to develop methane prediction equations for dairy cattle. Second, nitrogen balance data were compiled to define the

average excretion of manure and N in order to develop empirical equations for estimating excretion from Holstein dairy herds varying in milk production. Mean predicted excretion of manure (wet feces plus urine) for cows that averaged 29 kg/d of milk production concurred with the American Society of Agricultural Engineers (ASAE) standard, however predictions of N excretion were higher than ASAE predictions. Excretion of manure and N were substantially lower than the ASAE standards for cows that averaged 14 kg/d of milk production or nonlactating cows. Growing and replacement cattle excreted more manure and N than values reported by the ASAE for beef. Estimation of manure and N excretion was

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more accurate than mean values when using regression equations that included variables available to producers. Accurate estimates of excreta output will improve the planning of storage and handling systems for manure and the calculation of nutrient balances on dairy farms.

6. What do you expect to accomplish during the next year?

Initial objectives will be the completion of analysis of dairy cow visceral tissue samples where the effect of stage of lactation on visceral tissue mass is being studied. Additionally, the completion of analysis of the experimental data from a study in which the subtheraputic feeding of the antibiotic chlortetracycline and protein intake was related to gut tissue growth and whole body tissue deposition. Samples are either being analyzed or the data are being developed for publication after a seven-month delay in resource availability for sample processing, due to a moratorium on laboratory spending. A cooperative research agreement will be finalized with Cargill facilitating the investigation of a genetically engineered corn variety and its impact on rumen fermentation and whole body energy balance in lactating and non-lactating dairy cows. Conduct and complete experiments investigating the effects of ruminal vs. post-ruminal starch infusion on visceral energy use, whole body energetics, and glucose intermediary metabolism. The CRIS is scheduled to be terminated and rewritten in FY '99 pending the outcomes of a workshop to be held in January 1999, new specific objectives will be developed. However, many of the objectives will likely be consistent with those in this CRIS project, striving to determine the underlying mechanisms regulating visceral use and assimilation of nutrients and the effect of visceral growth and metabolism on animal productive efficiency as well as nutrient losses to the environment.

7. What technologies have been transferred and to whom? When is the technology likely to become available to the end user (industry, farmer, other scientists)? What are the constraints, if known, to the adoption durability of the technology?

A rumen epithelial cell isolation procedure has been refined and has been taught to other scientists either through visits to Beltsville or through invited presentations at national meetings. This same isolated cell system, in combination with dietary treatments applied to growing lambs, has led to the development of parameter estimates for ruminal energy substrate use which are novel and will be of importance to the development of more complete feeding models. Demonstrating that the change in visceral energy use associated with increased energy intake and decreased energy density is largely attributable to gut growth

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allows further investigation to focus on the growth related issues while continuing to gather important data regarding specific nutrient use by the visceral tissues. All of these technologies are available to other scientists through the literature and while basic in nature, will be included in the continuing refinement of mechanistic models to describe animal feeding systems. Additionally, a specific cooperative agreement is being developed with Cargill and trust arrangements with Roche animal health are in place for specific research objectives. Ultimately, the hope is that a complete understanding of the role of the visceral tissues can be established such that it can be controlled, in a beneficial manner, to minimize nutrient waste to either decrease the cost of production or decrease the negative effects of animal production on the environment.

8. List your most important publications and presentations, and articles written about your work (up to three total--NOTE: this does not replace your reviewed publications which are listed below)

BALDWIN, VI, R.L. 1997. Use of isolated ruminal epithelial cells in the study of rumen metabolism. J. Nutr. 128(Suppl. 2): S293-S296.
BALDWIN, VI, R.L., MCLEOD, K.R. and DAWSON, T.E. 1998. Influence ... sheep. In: K.J. McCracken, et al., Energy ... Animals; Proceedings of ... Energy Metabolism. Newcastle, Northern Ireland. pp. 55-58.
MCLEOD, K.R. and BALDWIN, VI, R.L. 1998. Influence ... sheep. In: K. J. McCracken, et al., Energy ... Animals; Proceedings of the 14th Symposium on Energy Metabolism. Newcastle, Northern Ireland. pp. 31-34.

PUBLICATIONS:
01.
BALDWIN, VI, R.L., MCLEOD, K.R. and DAWSON, T.E. 1998. Influence ... sheep. IN: K.J. McCracken, et al., Energy ... Animals; Proceedings of ... Energy Metabolism. Newcastle, Northern Ireland. pp. 55-58.

02.
BOHNERT, D.W., LARSON, B.T., BAUER, M.L., BRANCO, A.F., MCLEOD, K.R.,

HARMON, D.L. and MITCHELL, JR, G.E. 1998. Nutritional ... performance and nutrient flow and disappearance. J. Anim. Sci. 76:2474.

03.
MCLEOD, K.R. and BALDWIN, VI, R.L. 1998. Influence.. sheep. IN: K. J. McCracken, et al., Energy ... Animals; Proceedings of the 14th Symposium on Energy Metabolism. Newcastle, Northern Ireland. pp. 31-34.

04.
GLENN, B.P. 1998. Emerging strategies in ruminant nutrition: Where we are and new tools for the future. Southwest Nutr. Conf., p 1-16, University of Arizona.

Publications: (Continued)

05.
KNOWLTON, K.F., GLENN, B.P. and ERDMAN, R.A. 1998. Performance, rumen fermentation, and site of starch digestion in early lactation cows fed corn grain harvested and processed differently. J. Dairy Sci. 81:1972.

06.
BALDWIN, R.L., MCLEOD, K.R., RUMSEY, T.S., ELSASSER, T.H. and KAHL, S. 1998. Influence of chlortetracycline ... of growing beef steers. FASEB J. 12(5):A851.

07.
MCLEOD, K.R., RUMSEY, T.S., ELSASSER, T.H., KAHL, S. and BALDWIN, VI, R.L. 1998. Chlortetracycline affects ... with thyrotropin releasing hormone. FASEB J. 12(5):A852.

Approved: D.F. COLE Date: 02/99
Title: ACTING ASSOCIATE DIRECTOR

***OFFICIAL***

ANNUAL RESEARCH PROGRESS REPORT
Report of Progress (AD-421)

Accession: 0400102 Year: 98 Project Number: 1265-31000-064-00 D
Mode Code: 1265-50-00 STP Codes: 3.1.4.2 75% 3.1.4.5 25%
NATL PROG(S) 102 Animal Production Systems 100%

Title: IMPROVE ENERGY AND PROTEIN SUPPLY FROM RUMINAL FERMENTATION BY THE LACTATING DAIRY COW

Period Covered From: 01/98 To: 12/98

Progress and Outcomes:

1. What major problem or issue is being resolved and how are you resolving it?

The dairy cow in early lactation is in negative energy and protein balance, meaning she requires more energy and protein for milk production than she can consume. Dairy producers have a problem feeding the early lactation cow so that her energy and protein requirements are met. Efficiency of milk production is reduced during lactation if her nutrient requirements are not being met from the diet she consumes. Our research studies how the rumen, the cows largest stomach, digests different feedstuffs so that more usable energy and protein are derived for milk production. To better understand digestion of feedstuffs, a primary emphasis has been developing methods to analyze feedstuffs to better understand their nutritive value for cows.

2. How serious is the problem? Why does it matter?

Every early lactation dairy cow undergoes negative energy balance. In later stages of lactation, there are other reasons that different diets will over or under feed the cow. Therefore the losses in milk production due to our inability to meet the energy and protein requirements of the cow are quite large over an annual 305-day lactation. A part of that loss in milk production is also due to our lack of understanding of the chemical composition of the feedstuffs. This is an important problem because animal well being is affected, in addition to the economic loss in reduced milk production.

3. How does it relate to the National Program(s) and National Program Component(s) to which it has been assigned?

The research is appropriately conducted under the National Program in Animal Production Systems and the National Program Component of Animal Nutrition.
Our research studies how the rumen, the cows largest stomach, digests different feedstuffs so that more usable energy and protein are derived for milk production. To better understand digestion of feedstuffs, a primary emphasis has been developing methods to analyze

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feedstuffs to better understand their nutritive value for cows.

4. What was your most significant accomplishment this past year?

Our significant accomplishments were twofold. The first accomplishment was to demonstrate that increasing level of ruminally fermentable starch in the diet for lactating dairy cows increased starch digestibility. Dairy cows were fed alfalfa-based diets with different ratios of dry ground corn to high moisture ground corn. Increasing proportions of high moisture corn in the diet resulted in increased dry matter intake and milk yield that indicated the best ratio of dry corn to high moisture corn was 40:60. The use of a moisture of 40:60 ground dry corn:ground high moisture corn in dairy diets provides more energy than dry ground corn alone. Since intake is also increased, the combination of corn sources results in improved milk production by dairy cows. The second accomplishment was to demonstrate that feedstuffs can be analyzed for chemical composition more accurately using a technology that is similar in rapidity, but more accurate than the current industry standard. Work utilizing as is food ingredient powders demonstrated that mid-infrared diffuse reflectance spectroscopy can be utilized in the same manner as near-infrared reflectance spectroscopy for discriminant analysis. It was also demonstrated that mid-infrared spectral libraries can be built and used to identify food ingredient powders in the same manner as presently being done with near-infrared spectra. These results, along with previous work, demonstrate that the mid-infrared spectral range can be utilized for many of the same analysis presenting done using near-infrared spectra with the added advantage of increased ease of spectral interpretation.

5. Describe your major accomplishments over the life of the project, including their predicted or actual impact

There are two major accomplishments. First the discoveries from

our research on starch use by dairy cows have made a major contribution to the dairy industry. From at least 6 experiments with lactating dairy cows, an intensive volume of information on effects of corn harvest method and processing has uncovered basic information on the relationship between site of starch digestion and energy metabolism. Actual impact has been to inform the dairy producers regionally and nationally such that there are an increasing number of dairy producers processing starch sources for dairy diets. Second the discoveries from our research on rapid methods for analysis of feedstuffs has made a major

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contribution to the feed industry. From at least 8 experiments comparing the industry standard method, near infrared spectroscopy, to mid-infrared spectroscopy, we have determined that mid-IR can be used in the same manner as near-IR for analysis of feedstuffs. In addition, mid-IR has been shown to be more accurate. At least one industry giant in the food processing area has collaborated with Dr. Reeves on research and is developing plans to use the mid-IR technology.

6. What do you expect to accomplish during the next year?

This CRIS is scheduled to be terminated and rewritten in FY 99.

7. What technologies have been transferred and to whom? When is the technology likely to become available to the end user (industry, farmer, other scientists)? What are the constraints, if known, to the adoption durability of the technology?

Knowledge on starch use by dairy cows and effects of harvest method and processing has been transferred to dairy producers, extension personnel, industry personnel, and other scientists at dairy producer conferences, nutrition conferences, national and international scientific meetings as well as in publications in lay dairy press, as abstracts of professional society meetings, in refereed journals and in proceedings. The Net Energy Value for Lactation for high moisture corn has been reviewed for inclusion into the next edition of the NRC Nutrient Requirements of Dairy Cattle. Dairy producers are finely grinding high moisture corn for its added energy value. The primary constraint to adopting grain processing methods is capitol required to purchase equipment. High milk prices will make grain processing more attractive to dairy producers. Also, regulatory nutrient management planning for concentrated animal feeding operations will stimulate producers to look at grain processing for dairy cows.

Knowledge on near infrared and mid infrared spectroscopy techniques has been transferred to nutritionists, extension personnel, industry personnel, and other scientists at spectroscopy and animal producer conferences, national and international scientific meetings as well as in publications in lay press, as abstracts of professional society meetings, in refereed journals and in proceedings. A college level course was taught on mid- and near- IR at the University of Bologna in Italy. Industries using feedstuff analysis from animal feed industry to human food processors have shown interest in the new

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technology.

8. List your most important publications and presentations, and articles written about your work (up to three total--NOTE: this does not replace your reviewed publications which are listed below)

REEVES, III, J.B. and ZAPF, C. M. 1998. Mid-infrared diffuse reflectance spectroscopy for discriminate analysis of food ingredients. J. Agric. Food Chem. 46:3614-3622.
KNOWLTON, K. F., GLENN, B. P., and ERDMAN, R. A. 1998. Performance, ruminal fermentation, and site of starch digestion in early lactation cows fed corn grain harvested and processed differently. J. Dairy Sci. 81:1972-1984.
KNOWLTON, K. F., DAWSON, T. E., GLENN, B. P., HUNTINGTON, G. B., and ERDMAN, R. A. 1998. Glucose metabolism and milk yield of cows infused abomasally or ruminally with starch. J. Dairy Sci. 81:3248-3258.

PUBLICATIONS:
01.
GLENN, B.P. 1998. Emerging strategies in ruminant nutrition: Where we are and new tools for the future. Southwest Nutrition Conference. p. 1-16. Univ. Arizona.

02.
GLENN, B.P., DAWSON, T.E., LEFCOURT, A.M. and WILKERSON, V.A. 1998. Effects of level of high moisture corn in alfalfa-based rations on starch digestion by mid lactation cows. J. Dairy Sci. 81 (Suppl. 1):336.

03.
KALSCHEUR, K., KOHN, R.A., GLENN, B.P. and ERDMAN, R.A. 1998. Evaluating protein requirements predicted by the NRC and a modified version of the NRC. J. Dairy Sci. 81(Suppl. 1):349.

04.

KNOWLTON, K.F., GLENN, B.P. and ERDMAN, R.A. 1998. Performance, ruminal fermentation, and site of starch digestion in early lactation cows fed corn grain harvested and processed differently. J. Dairy Sci. 81:1972-1984.

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KNOWLTON, K.F., DAWSON, T.E., GLENN, B.P., HUNTINGTON, G.B. and ERDMAN, R.A. 1998. Glucose metabolism and milk yield of cows infused abomasally or ruminally with starch. J. Dairy Sci. 81:3248-3258.

06.
REEVES, III, J.B. and ZAPF, C.M. 1998. Mid-infrared diffuse reflectance spectroscopy for discriminate analysis of food ingredients. J. Agric. Food Chem. 46:3614-3622.

Approved: D.F. COLE Date: 02/99
Title: ACTING ASSOCIATE DIRECTOR

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ANNUAL RESEARCH PROGRESS REPORT
Report of Progress (AD-421)

Accession: 0401555 Year: 98 Project Number: 1265-31000-064-01 T
Mode Code: 1265-50-00 STP Codes: 1.2.2.4 50% 3.1.4.2 50%
NATL PROG(S) 102 Animal Production Systems 100%

Title: DEVELOPMENT OF SUSTAINABLE DAIRY MANURE MANAGEMENT PRACTICES TO ENHANCE FARM PROFITABILITY

Period Covered From: 02/98 To: 12/98

Progress and Outcomes:

1. What major problem or issue is being resolved and how are you resolving it?

Manure management is a major issue in animal agriculture because of its effect on environmental quality and on consumer desires for clean air, water, and food. Currently, there is a draft USDA, EPA Joint Strategy for Animal Feeding Operations being considered under the Clean Water Act which outlines both voluntary and regulated comprehensive nutrient management plans for most animal feeding operations in the US. This Strategy, if enacted, will have major impact on how livestock producers do business. This Fund for Rural America grant was received in May, 1998 and is a three-year grant. Our objective is to develop management practices and decision aids for operating a sustainable whole-farm dairy to handle manure in a profitable and efficient manner while avoiding detrimental effects on soil, water, and air quality. This goal will be accomplished in cooperation with our partners through a comprehensive integration of research, technology transfer and product/service development.

2. How serious is the problem? Why does it matter?

The problem is very serious. Perceived and actual impairment to the environment is a major negative issue for the animal agriculture industry, especially when manure management also is suggested to affect food safety.

3. How does it relate to the National Program(s) and National Program Component(s) to which it has been assigned?

This grant is highly appropriate for the multiple National Programs to which it has been assigned. Research conducted is a part of the National Program of Animal Production Systems, including the National Program Components of Animal Nutrition and Integrated Information. Research conducted also is a part of the National Program of Manure and Byproduct Utilization, including the National Program Components of Collection, Treatment and Storage of Byproducts; Land Application Protocols; Evaluation and Development of Best Management Practices; Alternative Approaches

Accession: 0401555 Year: 98 Project Number: 1265-31000-064-01 T
Mode Code: 1265-50-00 STP Codes: 1.2.2.4 50% 3.1.4.2 50%
NATL PROG(S) 102 Animal Production Systems 100%

to Byproduct Utilization; and Decision Support Tools. It is one of a few efforts in ARS to use a multi disciplinary approach toward solving problems of nutrient management on farms.

4. What was your most significant accomplishment this past year?

Our most significant accomplishment this past year was a stakeholder workshop which was held on the topics of dairy cattle nutrition, land application, and whole farm nutrient management systems. We held a workshop at Cornell University with grant participants from USDA, ARS, Pennsylvania State University, University of Vermont, Cornell University, and the Northeast Dairy Herd Improvement Association. The University of Vermont's decision support system for nitrogen management was reviewed. The Cornell Nutrient Management Planning System was reviewed and then gaps in the system were discussed. Potential collaborative research was developed to fill in the gaps. A second workshop was planned on composting. Plans were made for measuring nutrient runoff in wetlands from the Beltsville dairy unit.

5. Describe your major accomplishments over the life of the project, including their predicted or actual impact

The project was started in June of 1998.

6. What do you expect to accomplish during the next year?

A postdoctoral scientist will conduct research in nutrient management and serve as a liaison to the stakeholder collaborative research projects. Specific collaborative research projects will be conducted.

7. What technologies have been transferred and to whom? When is the technology likely to become available to the end user (industry, farmer, other scientists)? What are the constraints, if known, to the adoption

durability of the technology?

Specifically from this grant, no technologies have been transferred.

8. List your most important publications and presentations, and articles written about your work (up to three total--NOTE: this does not replace your reviewed publications which are listed below)

Our most important presentation was the Workshop held at Cornell

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University.

PUBLICATIONS:

Approved: D.F. COLE Date: 02/99
Title: ACTING ASSOCIATE DIRECTOR

ANNUAL RESEARCH PROGRESS REPORT
Report of Progress (AD-421)

Accession: 0400107 Year: 98 Project Number: 1270-12310-001-00 D
Mode Code: 1270-05-00 STP Codes: 1.2.2.4 40% 3.1.4.2 60%
NATL PROG(S) 102 Animal Production Systems 60%
206 Manure and Byproduct Utilization 40%

Title: SUSTAINABLE SYSTEMS FOR MANAGING MANURE FROM DAIRY CATTLE

Period Covered From: 01/98 To: 12/98

Progress and Outcomes:

1. What major problem or issue is being resolved and how are you resolving it?

The problem or issue being resolved is manure management on U.S. livestock farms. The dairy industry is facing a manure management problem. The public is concerned that manure management, particularly on large dairy farms, is degrading the quality of the nation's ground waters, surface waters, estuaries, and atmosphere. This project will help remedy this problem by developing feeding strategies, manure management practices, and land application techniques which will: reduce nutrient excretion, keep nutrients on the farm, reduce odors, and maintain farm profitability.

2. How serious is the problem? Why does it matter?

The problem is very serious. Perceived and actual impairment of water and air quality is a major negative issue for the animal agriculture industry. Currently, there is a draft USDA-EPA Joint Strategy for Animal Feeding Operations, formulated under The Clean Water Act, which outlines both voluntary and regulated nutrient management plans for most U.S. animal feeding operations. This strategy, if enacted, will have a major impact on U.S. livestock industries because it will mandate the development of manure management plans for large animal enterprises. In order to develop these manure management plans for the site-specific conditions of individual farms, the agriculture advisory community must have a wide choice of manure management tools and strategies based on a whole-farm system.

3. How does it relate to the National Program(s) and National Program

Component(s) to which it has been assigned?

This research is a multi-disciplinary cross cutting project and relates to multiple national programs. The research is a part of the National Program of Animal Production Systems, including the National Program Components of Animal Nutrition and Integrated Information. The research is also a part of the National Program of Manure and Byproduct Utilization, including the National Program Components of Collection, Treatment and Storage of Byproducts; Land Application Protocols; Evaluation and Development of Best Management Practices; Alternative Approaches to Byproduct Utilization; and

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Decision Support Tools. It is one of a few efforts in ARS to use a multi-disciplinary approach toward solving problems of nutrient management on farms. The project relates to all these areas because the project is designed to research and develop feeding strategies, manure management tools, and land application techniques for whole-farm systems for efficient and environmentally sound utilization of dairy manure.

4. What was your most significant accomplishment this past year?

Controlling ammonia accumulation in the rumen can reduce N excretion by the dairy cow. Effects of cow diets on rumen ammonia loss was studied with rations containing orchardgrass silage, fertilized with two rates of N as liquid dairy slurry, combined with either ground corn, barley, or sorghum. Ammonia accumulation was lower with the low N fertilized grass in the diet compared to the high N fertilized grass. Ammonia accumulation was lower for diets containing sorghum, intermediate for corn, and highest for barley. This research shows that ammonia accumulation in the rumen can be affected by diet and that optimal control of ammonia accumulation will depend on the combination of grass and grain in the diet.
Farmers should apply manure at rates consistent with nutrient availability to the crop. There are no fast methods for measuring organic N mineralization, which necessitates manure sample storage before analysis. Storage methods of: refrigeration, freezing, freeze- and ove-drying were evaluated to determine their effect on N and C mineralization of dairy slurries. Freeze- and oven-drying resulted in N losses of 30% or more and in greater N immobilization, compared with fresh manure. These results show that oven- and freeze-drying are unsuitable methods of storage, but that manure was not affected by refrigeration or freezing.

5. Describe your major accomplishments over the life of the project, including their predicted or actual impact

The research on starch use by lactating dairy cows has shown that increasing the ruminal fermentability of dietary corn, by harvest method or processing, dramatically improves N digestion and reduces fecal N and P

excretion by 11-13% and urinary N and P excretion by 24-37%. The impact of this research has been an increasing number of dairies, regionally and nationally, that are now using high moisture corn to improve N digestion in dairy cattle.

Fresh manure commonly losses about half of its ammonium N through volatilization. This loss reduces the fertilizer value and has been linked to environmental damage. Ammonia volatilization was measured for 7 days with small wind tunnels from fresh manure collected from mid-lactation cows fed diets of: orchardgrass at 30% NDF, alfalfa at 30% NDF, or orchardgrass at 35% NDF. Rapid ammonia losses occurred the first 72 hours,

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then losses became negligible. Losses were not significantly affected by diet. The ammonia loss amounted to 34% of the total initial manure N, or 134% of the initial urine N. Thus, about 15% of the initial organic N was lost as ammonia within 72 hours. This research impacts the design of manure management strategies aimed at conserving ammonia. Ammonia conservation measures must act within a few hours if they are to minimize ammonia volatilization.

Manure management requires a whole-farm strategy which includes the efficient rations that meet the nutritional needs of the animals, manure handling systems with on-farm treatment options, and nutrient utilization in a forage- or grain-crop system. Two extensive literature reviews and critical analyses were written on manure management in modern livestock systems. These showed that modern livestock farms are importing many more nutrients than they are exporting, which is leading to a build-up of soil bound nutrients (such as P) and a loss of mobile nutrients (such as N) through ammonia volatilization, nitrate leaching, and/or denitrification. The loss of N and build-up of P can be demonstrated to farmers through on-farm nutrient budgets. Farmers have several tools to improve manure nutrient use, but current tools lack a whole-farm philosophy. This analysis has underscored a critical need for whole-farm decision support systems in order to improve nutrient use efficiency in modern livestock systems. The review and analysis papers are being used by scientists, NRCS agents, and nutrient management consultants in the Northeast to define the nature and extent of the manure nutrient problem and to identify areas where better decision support tools are needed; e.g., whole-farm nutrient budgets, ammonia volatilization, and an environmental based P index.

6. What do you expect to accomplish during the next year?

Research this year will include intensive studies of manure quick tests. This will involve a thorough literature review and extensive field testing utilizing manures from across the Mid-Atlantic region. The test will compare the precision, accuracy, and practical usefulness of the tests and compare them to traditional laboratory tests as well as evaluate the potential of near-infrared spectroscopy as a possible new analytical

technique.
Preliminary studies have shown that chemical additives of alum or zeolites can reduce ammonia volatilization from dairy slurry. Small wind tunnels will be used to measure ammonia losses resulting from unamended slurry and from the addition of 2.5% of either alum or zeolites. The chemistry involved in the ammonia conservation ability of these additives will be studied through closed vessel incubations. These data will develop a better understanding of their mode of action and thereby develop more optimal protocols for their potential use in on-farm liquid dairy manure systems.

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The design, construction, and initial testing of a new large-scale environmental chamber will be completed. The chamber will allow measurement of gaseous emissions from housed animals, compost piles, or stored manure. Instrumentation will allow real-time measurement of ammonia, methane, carbon dioxide, and hydrogen sulfide. Next years' plans call for the examination of environmental factors and management factors on gaseous emissions. Gas measurement capabilities will be expanded to measure odorous compounds, in addition to ammonia and hydrogen sulfide, to determine if a limited number of compounds can be used to generate an "odor index" to quickly distinguish objectionable odors. The long-term goal is to develop a practical instrument to measure this "odor index," and to correlate measurements with real farm odor problems.

7. What technologies have been transferred and to whom? When is the technology likely to become available to the end user (industry, farmer, other scientists)? What are the constraints, if known, to the adoption durability of the technology?

Knowledge on starch use by dairy cows and effects of harvest method and processing has been transferred to dairy producers, extension personnel, industry personnel, and other scientists at dairy producer conferences, nutrition conferences, national and international scientific meetings as well as in publications in lay dairy press, as abstracts of professional society meetings, in refereed journals and in proceedings. The Net Energy value for Lactation for high moisture corn has been reviewed for inclusion into the next edition of the NRC Nutrient Requirements of Dairy Cattle. Dairy producers are finely grinding high moisture corn for its added energy value. The primary constraint to adopting grain processing methods is capital required to purchase equipment. High milk prices will make grain processing more attractive to dairy producers. Also, regulatory nutrient management planning for concentrated animal feeding operations will stimulate producers to look at grain processing for dairy cows.

8. List your most important publications and presentations, and articles written about your work (up to three total--NOTE: this does not replace your

reviewed publications which are listed below)

KNOWLTON, K.F., GLENN, B.P. and ERDMAN, R.A. 1998. Performance, ruminal fermentation, and site of starch digestion in early lactation cows fed corn grain harvested and processed differently. J. Dairy Sci. 81:1972-1984.

MEISINGER, J.J. and THOMPSON, R.B. 1996. Improving nutrient cycling in animal agriculture systems. Animal agriculture and the environment. pp. 92-110. Proc. Northeast Region Ag. Eng. Serv., NRAES-96, Ithaca, NY.

LEFCOURT, A.M., GLENN, B.P., MCCONNELL, L., MILLNER, P. et al. 1997.

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206 Manure and Byproduct Utilization 40%

Sustainable systems for managing manure from cows. Proc. SE Sustain. Anim. Waste Man. Workshop p.311-312. Univ. GA ENG978-001, Athens, GA.

PUBLICATIONS:

01.
GLENN, B.P., DAWSON, T.E., LEFCOURT, A.M. and WILKERSON, V.A. 1998. Effects of level of high moisture corn... digestion by mid-lactation cows. J. Dairy Sci. 81(Suppl. 1):336.

02.
KALSCHEUR, K., KOHN, R.A., GLENN, B.P. and ERDMAN, R.A. 1998. Evaluating protein requirements predicted by the NRC and a modified version of the NRC. J. Dairy Sci. 81(Suppl. 1):349.

03.
KNOWLTON, K.F., GLENN, B.P. and ERDMAN, R.A. 1998. Performance, ruminal fermentation, and site of starch digestion ... harvested and processed differently. J. Dairy Sci. 81:1972-1984.

04.
LEFCOURT, A.M., MEISINGER, J.J., WILKERSON, V.A., VANKESSEL, J.S., GLENN, B.P. and THOMPSON, R.B. 1998. Ammonia release and nitrogen loss from fresh dairy manure. J. Dairy Sci. 81(Suppl. 1):262.

05.
LEFCOURT, A.M. and ADAMS, W.R. 1998. Radiotelemetric measurement of body temperature of feedlot steers during winter. J. Anim. Sci. 76:1830-1837.

06.
SHARPLEY, A.N., MEISINGER, J.J., et al. 1998. Impacts of animal manure ... water quality. IN: J.T. Hatfield and B.A. Stewart (eds.) Animal waste ... as a soil resource. Ann Arbor Press, Chelsea, MI.

07.

VAN KESSEL, J.S., REEVES, III, J.B., MEISINGER, J.J. and WILKERSON, V.A. 1998. The effect of forage source ... carbon and nitrogen mineralization. J. Dairy Sci. 81(Suppl. 1):262.

08.
VOUGH, L.R., MIN, D.H., CHEKOL, T. and MEISINGER, J.J. 1998. Top-dressed dairy slurry on alfalfa-grass: effects on soil N and P levels. Agronomy Abstracts p. 315.

09.
WILKERSON, V.A., GLENN, B.P. and MCLEOD, K.R. 1997. Energy and N balance in lactating cows fed ... dry or high moisture corn ... in rolled or ground form. J. Dairy Sci. 80:2487-2496.

Publications: (Continued)

10.
WILKERSON, V.A., MERTENS, D.R., GLENN, B.P. and VAN KESSEL, J.S. 1998. The effect of dietary forage sources ... cows in mid to late lactation. J. Dairy Sci. 81(Suppl. 1):262.

11.
WOODWARD-GREENE, M.J., DAWSON, T.E., GLENN, B.P. and ERDMAN, R.A. 1998. Effect of starch source and level of orchardgrass ... ammonia and VFA production. J. Anim. Sci. 76(Suppl. 2):83.

Approved: D.F. COLE Date: 02/99
Title: ACTING ASSOCIATE DIRECTOR