Metabolic Profiling to Evaluate Nutritional and Disease Status[a]

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Introduction

Nutritional problems on a dairy farm may range from the simple to extremely complex. Simple problems may result from a single nutrient deficiency, inappropriate mixing of the diet or inadequate feeding facilities, whereas complex problems may involve interactions between nutrition, environment and feeding management. Problems may be acute or chronic in occurrence; they may be blatantly obvious or insidious. Determining if a problem exists on a dairy farm involves coordination of a number of people and appropriate interpretation of available information. In many situations, reliable and useful information to make some determination of a problem is unavailable. Another problem may be in having all parties in agreement as to the existence of a problem and its severity. If any diagnostic endeavor is to culminate in some satisfactory endpoint, producers must be convinced of the existence of a problem which, if properly resolved, will result in some economic benefit to their dairy operation. **We, the agricultural support services community, may be the best diagnosticians in the world but if our producer is not convinced of a problem, we have no possible road to take in its potential resolution. Therefore, effective client communication is a critical entity in the diagnostic process.**

In interpreting data from a diagnostic investigation, no one person can be an expert in all fields. As a result, diagnostic investigations should be the result of an integrated team effort. Veterinarians generally have ready access to animal health, body condition, mastitis and reproductive performance information and are on the farm more frequently. Farm nutritional programs are engineered by a wide variety of nutritional consultants. The veterinarian and nutritional consultant are both working to improve the economic well being of the dairy producer. One would believe that the veterinarian and nutritionist should have a mutually interactive working relationship in the transference of ideas and information relative to their common dairy client. Unfortunately in the real world this does not happen as often as one would like. One goal of this workshop is an attempt to bring these two groups together from a standpoint of mutual understanding. Veterinarians often use blood metabolite analysis to conclude potential nutritional problems. Nutritionists are often uncertain of the validity or interpretation of this information and can become defensive about their nutrition program. We feel that if both groups better understand the practical application of metabolic profiles, its limitations and potential uses, a more positive interaction between the two groups can ensue with the bottom line being greater benefit to the dairy producer. The focus of this workshop is to review the diagnostic process relative to nutritional evaluations with emphasis on one portion of the diagnostic evaluation process, metabolic profiling as it relates to nutritional status. The objective of this presentation is to provide an overview of the nutritional diagnostic process. An accompanying presentation will provide a detailed discussion of the metabolic profile and its interpretation.

Nutritional Diagnostic Evaluations - an Overview of Methods

Diagnostic evaluations of a dairy herd can be frustrating to all parties, especially when no real solution has been found. There are four steps to the diagnostic process: 1. identify and confirm the presence of a problem; 2. determine key factor(s) causing the problem; 3. enact measures to correct the problem; and 4. establish procedures to prevent further problems.[1] The evaluation process ideally should be a team effort between producer, nutritionist and veterinarian with additional input from extension specialists as needed. When a meticulous and methodic diagnostic protocol is not en-

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acted, the result more often than not is unrewarding. Unfortunately, the producer always is the one which stands to lose the most in such situations. Blood analyses always seem to be the "ace in the hole" relative to diagnostic dilemmas and often are used somewhat indiscriminately to fish for answers. Unfortunately, blood profiles may be the least likely diagnostic aid to bring forth useful results, besides the fact that they are the most expensive diagnostic tool. One must remember that blood analysis is only one portion of the diagnostic tools to be used. When blood metabolite analysis is used in conjunction with animal and facility evaluation, body condition scoring and ration evaluation in a team approach, it can be a useful diagnostic tool for evaluating dairy herd nutritional and health status.

Records Analysis

It has been said that if you don't know where you are today you can not possibly know where you are going. Records, when properly organized and analyzed, form the basis for making sound management decisions by providing current as well as historic information. Dairy enterprises are increasingly complex businesses with multiple layers of management as well as multiple sources of outside information. The ability to make the business prosper requires a team approach to problem solving and records form the basis for managing this team.

When we think of records we tend to think only of the packet which arrives monthly and gets stashed on a shelf somewhere after the barn book has been removed. In a broad sense, however, records constitute any information which is currently being recorded. How useful this information is to management depends a lot on how it is organized and reviewed.

Thorough use of records can help the consultant in three ways: problem diagnosis, marketing and ongoing monitoring. When working to diagnose current problems, records are part of a broad assessment which needs to be done to identify all significant factors relating to a problem. Information regarding animal behavior, clinical signs of disease, cow environment, production, metabolic status and even financial information may need to be combined to achieve lasting solutions to production problems.

The inability to implement effective solutions many times stems from either a discrepancy between perception and reality, (i.e., my lameness problem is foot warts when in fact a majority of the problem is subclinical laminitis) or the inability to establish temporal relationships (i.e., the relationship between poor dry cow management and peak milk yields).[1] Records can be the key to our ability as consultants to clearly show the problem, market solutions and motivate clients.

Ultimately, records need to be designed to focus management on areas which need attention as early as possible without unnecessarily squandering resources on problems which do not exist. As consultants trained in critical evaluation and problem solving, we can provide valuable advice regarding design of records systems as well as evaluation and implementation of collected information.

Nutritionists and veterinarians alike are constantly being asked why discrepancies exist between formulated rations and apparent response. Often the system of monitoring is not sensitive enough to notice if a response did indeed occur. Sometimes what gets delivered to the cow is not what was formulated, and often factors exist which limit the cows ability to respond even though appropriate rations are being delivered. Records many times are the only way to sort this out. The following are some areas which can provide valuable information about the nutrition program.

Cow Inventories

Lack of accurate records of cow inventories many times are the primary reason changes in daily milk yields can not be properly assessed. What is in the bulk tank is the truest assessment of milk yield, however, the value of this piece of information is often diluted by not knowing how many animals actually contributed. It is important to remember that even when cow numbers are being tracked closely, the amount of milk being dumped may be significant enough to affect results.[1]

Distributions of cow inventory by stage of lactation as well as lactation number may also be important in assessing an apparent lack of response.[2] Cow inventory information is often overlooked as it relates to facilities. Cow numbers vs feed bunk space and free stall numbers may be significant. Grouping of cows vs parlor efficiency may have significance both by affecting time in parlor if feed is delivered there or by limiting time at the feed bunk.[3,4]

Clinical Disease

Disease prevalence is another opportunity to collect valuable information which is rarely exploited well. Problems may be a direct result of nutritional mismanagement or they may limit the animal's ability to respond to adequate nutrition. High priority should be given to minimizing problems which occur during the transition from dry to peak. How profitably a cow converts feed to milk across a given lactation has everything to do with how well she peaks and how well she meets her nutritional demands as she approaches peak. Metabolic problems which occur around the time of calving have profound effects not only on peak milk yields but also on survival rates within the herd. Table 1 lists some of the more important periparturient problems and suggested action levels.[5]

Table 1. Suggested action levels for periparturient diseases.

Periparturient Disease Process	Action Level (% of freshenings)
Milk Fever	> 6%
Subclinical Hypocalcemia	> 15%
Clinical Ketosis	> 3%
Displaced Abomasum	> 3%
Retained Placenta	> 8%
Mastitis (at calving)	> 5%

Feet are another clinical problem which can be the result of nutritional mismanagement or the reason for poor performance on adequate rations. Subclinical acidosis problems and subsequent laminitis may be difficult to pinpoint without the aid of ruminocentesis.[6] Infectious foot problems may limit standing time at the bunk and poor stall conditions may contribute to laminitis problems in the face of adequate ration management. Many times perception and reality differ significantly and good records on specific foot problems within herd can be extremely helpful.[6]

Monitoring reproductive performance can lend some insight into certain types of nutrition problems; often times however, further metabolic testing is extremely valuable in pinpointing problems. Energy balance, milk protein, milk urea nitrogen (MUN) data or tissue trace mineral analysis may help clarify dietary relationships which directly affect fertility.[7-10] Other relationships are less direct and may relate to early lactation or lameness problems for example. Finally, disease problems such as mastitis or pneumonia may limit the cow's ability to respond even when adequate rations are being presented.

Milk Production

Use of herd-based lactation curves stratified by parity, season, lactation groups and other factors has been advocated as a functional monitoring tool to assess production performance.[2,8,11-13] However, there is some question as to the usefulness of lactation curve data and more emphasis on interpretation of 305-day Mature Equivalent milk production data.[14,15] First test and peak milk are sensitive monitors of early lactation management. Monitoring butter fat and protein by lactation stage may show problems which are masked in the overall herd average. Caution needs to be used in relating current months profiles to past history. Monitoring early lactation solids (% butter fat and % protein for cows <14 DIM) may indicate problems with early lactation weight loss, however, monitoring NEFA may be a more sensitive way of pinpointing problems. It is extremely important to have some means to reconcile apparent milk yields from DHI with actual milk produced. If significant discrepancies exist conclusions may be drawn from DHI records which are misleading at best.

Dry Matter Intakes

Monitoring DMI on an ongoing basis is something which is talked about frequently, but very rarely done in a manner which impacts management decision making. Even in situations where lactating cow DMI is monitored fairly closely, it is rare to find the same attention being given to the dry and transition cows. Dry matter intake, cow inventories and milk yields when monitored together can provide a level of management control which may represent the next step which needs to be taken in many management situations.[16]

Youngstock

The performance of first lactation animals within the herd may be one reason for apparent poor responses to nutritional management. Monitoring performance of these animals separately is often eye-opening when compared to the resources being devoted to getting them to first freshening.[17] The effect on overall profitability of delayed days to first calving and/or poor first lactation yields is often seriously underestimated.

The cows are the ultimate indicator of production effects on the farm. Production records, formal body condition scoring programs and records of clinical disease are all ways of organizing what the cows are telling us. Strategic use of metabolic screening has greatest value when used as an integrated part of the production management process.

Animal and Facilities Evaluation

During a herd evaluation, one needs to use all of their senses to inspect the animals, their manure and body condition. Cows should be visually inspected for hoof and leg problems, haircoat, general condition and attitude, cud chewing activity[8] and body condition. Manure should be inspected for consistency, presence of grain seeds and length of fibrous particles. A similar inspection should be made of housing and feeding facilities.[4] Quantitative measurements of specific parameters (i.e., feedbunk size) should be made whenever possible. Interaction of the cow and her environment should also be evaluated. How many cows are using their stalls properly? Is there evidence of cow grouping, stress, overcrowding or other problems? Assess quality of ventilation, water quality and availability and access time to fresh feed.

Body Condition Scoring

Body condition at calving plays a pivotal role in determining subsequent health, productive and reproductive performance.[18,19] Moderate body condition is essential for support of milk production in early lactation, when milk energy output exceeds feed energy intake (i.e., negative energy balance) and to initiate reproductive cyclicity. Either extreme in body condition (emaciated or obese) results in reduced milk yield, increased health disorders and impaired fertility.[18,19]

Body condition scoring is a method which subjectively grades cows by the amount of subcutaneous fat stores over the loin, pelvis and tailhead into five categories covering physical states of emaciated (1), thin (2), average (3), fat (4) and obese (5).[20] Although subjective, visual methods of BCS have been validated across multiple observers.[21] As a diagnostic tool, BCS is the least expensive and yields excellent information relative to cow energy balance. However, BCS is often overlooked as a herd management tool because it is viewed as being too time consuming. Both nutritionists and veterinarians should educate their clients as to the positive benefits of having BCS data on a herd and reinforce this concept by routinely using the data as a herd monitor.[22]

Cows should be evaluated for body condition at dry off, calving, early lactation, time of breeding and late lactation. Recent data have found that differences in BCS can be seen in 30-day intervals across lactation and dry period.[23] This information reinforces the concept that routine BCS can be a useful diagnostic monitor of herd energy balance. Body condition score mean goals for the gestation-lactation cycle are to have cows dry off at 3.5, maintain this condition to calving, lose less than 1 condition score in early lactation, then regain condition back to 3.5 during late lactation. On a herd basis, condition loss in early lactation should average -0.75 units or less.

However, mean BCS values alone are not sufficient. Profiling BCS change across lactation can be misleading if one assumes that current information across cows in different stages of the lactation cycle is related. Also the use of average BCS for groups of cows may be misleading due to non-normal distribution. It may be more appropriate in some instances to look at distribution around a median. What one is really interested in is the potential problem cows, e.g., extremely thin and fat cows. Thin and fat cows together can produce a desirable group mean BCS, yet the majority of the animals are potential problems. Within each grouping, the percent of cows which have either too thin or too fat condition should be evaluated. Under intensive management conditions, less than 10% of the dry cows should have BCS either >4.0 or <3.0. For lactating cows, less than 10% should have a BCS < 2.5. Monitoring NEFA concentrations through the dry and transition period may provide a more sensitive way of establishing cause and effect when excess BCS loss is occurring in early lactation.

Ration Evaluation

It is often stated that there are three rations on the farm: the formulated ration, the feedbunk ration and finally the ration which the cow consumes.[8] Ideally all three rations should be equal relative to their nutrient content. Forage analysis of the ration from the feedbunk prior to and following consumption by the animals will allow for critical assessment of these three rations. Nutrient content differences between the formulated and feedbunk rations suggests ingredient composition variability, mixing errors or some combination. Significant differences between refused feed and feedbunk analyses would suggest sorting by the cows. Constant monitoring of forage and dietary ingredient quality is just as essential to the dry cow program as it is to the lactating cow program. Far too many clinical disasters occur as a result of a change in forage without any concern over differences in nutrient density or quality. Besides the more standard dry matter, protein, fiber and energy determinations, you should also have feed ingredients evaluated for macro- and micromineral concentrations. This aspect is absolutely critical if you wish to utilize anionic salts to overcome a nagging milk fever problem in a dry cow ration. Be sure to have chloride analysis included. Most labs do not include this mineral unless specifically requested.

Some have advocated that there is a fourth ration on the farm; the one the cow actually digests and absorbs.[8] It is this ration which would be most highly associated with animal health, reproductive and lactational performance. Theoretically, the only way in which to assess this ration would be to observe changes in blood or tissue nutrient concentrations relative to differences in nutrient content of the consumed ration. Metabolic profiles, even with their limitations, may be the better method of assessing this diet. Other more invasive techniques such as liver biopsy for mineral concentration analysis may also be of benefit, but a much more involved procedure on a herd basis.

Beyond ration nutrient density, other nutritional variables need to be evaluated, primarily particle size and rumen health as a function of diet. Particle size of a ration can be quantitatively evaluated using a particle size separating apparatus.[24] Qualitative evaluation of particle size can be completed by comparing the same ration ingredients mixed by hand to those by the mixer wagon. Overmixing of the ration with auger-style mixers can result in substantial reductions in particle size. Particle size reduction in conjunction with feeding excessive nonstructural carbohydrates can lead to

clinical and subclinical rumen acidosis and subsequent secondary problems like laminitis. Presence of this problem may be evaluated using rumenocentesis procedures to collect rumen fluid and measuring pH.[6]

Even if veterinarians do not feel comfortable with ration formulation, they can and should become involved in their clients' ration program in a role of monitoring agent. The veterinarian deals most directly with subsequent disease processes and visualizes the animals most often. Open lines of communication between the herd's veterinarian and nutritionist are needed. The herd veterinarian needs to provide the appropriate information relating to animal health and performance to the person who can do the most with it. All parties, including the client, will greatly benefit from such interactions.

Nutrient Profile Analysis

Clinical chemistry measures are commonly used in all veterinary hospitals as an aid in the diagnosis of individual animal health problems. Application of this diagnostic procedure has been advocated as a useful herd-based diagnostic tool to monitor and diagnose metabolic status and disease.[25-30] However, use of metabolic profiles as a diagnostic aid has been questioned relative to its validity and sensitivity in defining a problem as well as its cost.[31-34] A variety of factors including herd of origin, parity, physiologic state and stage of lactation are responsible for individual and herd variation in blood metabolite concentrations confounding interpretation.[33,35,36] In addition, the cow has an exquisite system of checks and balances (i.e., homeostatic regulation) which maintains normal physiologic function within a wide array of dietary and environment insults. This results in some blood metabolite parameters not having a normal distribution and thus confounding direct interpretation.[33,37] As a result of these physiologic regulatory mechanisms, simple blood concentration analysis has not been highly rewarding in accurately assessing nutritional and fertility status.[32-34]

An association between nutritional insults and reproductive and lactational performance has been well documented.[7,9,10,41] Energy and protein status are the primary nutrients of concern, although deficiencies as well as toxicities of many of the minerals and vitamins can also affect reproductive performance. Energy balance may be assessed through the use of body condition scoring or by the measurement of NEFA concentrations. Elevated NEFA concentrations are recognized around the time of calving and represent increased lipid mobilization to counter negative energy balance.[42] Prolonged or extreme lipid mobilization around calving can lead to elevated liver fat infiltration and increased periparturient disease problems.[42,43] Serum NEFA concentrations are very sensitive to energy balance in contrast to serum glucose concentrations as a result of serum glucose being homeostatically regulated. Protein status is more difficult to evaluate given the lack of any metabolite which is specifically affected by dietary protein. Concentrations of total protein, albumin, BUN and muscle enzyme activities are often used as measures of protein status. Recently, use of milk urea nitrogen (MUN) has been advocated as a more practical routine assessor of dietary protein status.[8,44] In assessing mineral and vitamin status of an animal, one needs to consider the potential role of homeostatic regulatory processes and nutrient reserves (i.e., liver nutrient storage). Both of these physiologic processes will help to buffer nutritional insults and minimize changes in blood mineral or vitamin content which might confound interpretation of the measured nutrient's concentration. Taking serum samples at times when the homeostatic processes are physiologically challenged and ineffective (i.e., around calving) may be the most appropriate time. Liver biopsy may be a useable method to assess liver storage of trace minerals and fat-soluble vitamins.

Unfortunately in many herd situations, blood analyses are used preferentially in lieu of other more appropriate diagnostic procedures such as ration evaluation and physical exams and without regard for proper technique to ensure sound diagnostic information. Despite these problems, blood metabolite analysis can reveal some useful diagnostic information if properly interpreted in conjunction with animal, facility and ration evaluations.[38-40] A modification of the traditional Compton Metabolic Profile as described by Payne,[25] using different metabolic tests and accounting for variation due to physiologic state and stage of lactation is presented in an accompanying paper.

Summary

The diagnostic process is one which most veterinarians are confronted on a daily basis. Some diagnostic problems are straightforward and do not require intensive investigative efforts. However, when a more troublesome problem is confronted, a strict methodical approach addressing the parameters outlined in this presentation should be considered. Infrequently will a problem be solved by investigating only one of the components discussed. **Most importantly it must be remembered that metabolic profiles are almost useless without being coupled with animal and facility evaluations, body condition scoring and ration evaluation. Metabolic profiles used in combination with other diagnostic measures within a team approach can be an extremely useful tool in nutritional evaluations of the dairy herd. It is only when the whole picture is evaluated will the**

use of metabolic profiles produce useful diagnostic information.

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