BENEFITS AND OPPORTUNITIES TO FORMULATING DAIRY RATIONS FOR INDIVIDUAL AMINO ACIDS

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The theoretical advantages of balancing dairy rations on an individual amino acid or ideal protein basis are now generally accepted but there has been reluctance by the dairy industry to put the principles into practice. Comments and views such as: responses are inconsistent, there is not enough information yet to evolve from formulating on just MP to individual amino acids, it is too expensive, it is just a story fabricated to sell protected amino acids, are still common.

However by evolving our current MP systems to incorporate the concept of amino acid balancing, the variability in predicting milk performance will be reduced. Yes the cost of a ration is likely to increase but the benefits will more than outweigh this cost. Yes, it will be necessary to use protected amino acids as they are an essential ingredient to achieve the best cost solution. At worst, for the same cost, a “better” ration can be formulated using amino acid balance principles rather than staying with the status quo.

REVIEW OF THE ADVANTAGES OF AMINO ACID NUTRITION

There are many good reviews in the literature summarizing the advantages to enriching rations in metabolizable lysine and methionine (NRC 2001, Rulquin and Verite, 1993, Sloan 1997,).

Similarly to poultry and swine, the premise, in dairy, is that by identifying the amino acids that are likely to limit milk protein synthesis and enriching the ration in these amino acids, this will maximize milk protein synthesis and the efficiency of utilization of all absorbed amino acids (metabolizable protein - MP). There is now a consensus in the literature that for most dietary situations the first two most limiting amino acids are methionine and lysine (NRC 2001). Methionine is nearly always first limiting, with the secondary lysine limitation varying from virtually a co-limitation with methionine to situations where MET supplies need to be increased by nearly 20% before LYS becomes a limiting factor.

In North American rations where corn is the only grain in the ration and some corn byproducts or brewers grains are fed, both LYS and MET levels in metabolizable protein will need to be improved to see a response. Where less reliance is placed on corn as the grain source and soybean meal is the principal protein source in the ration, often performance can already be improved by 30 to 70g of protein per day simply by increasing metabolizable methionine supplies by 5 to 10g per cow per day. The probable sequence of limitations of the next limiting amino acids after lysine and methionine is still somewhat speculative. Recent trials would suggest histidine (Korhohen et al 2000) as a likely candidate for the third limiting amino acid, particularly where no blood meal is being fed.

However the practical significance of being able to determine the subsequent limiting amino acids remains a relatively academic question in to-days environment. It is still a major challenge even to achieve 90% of estimated requirements for LYS and MET with the
ingredients currently available. Until these levels can be pushed higher, there is unlikely to be any issues of responses to LYS and MET being inhibited by any other amino acid limitation.

Garthwaite et al 1998 summarized the published feeding trials concerning enriching rations in metabolizable LYS and MET. For seven trials commencing immediately post calving or within the first two or three weeks of lactation and continuing to at least 120 days in lactation, daily milk yield was increased on average by 1.5 lbs of milk, milk protein yield by 80g/d and milk protein % increased +0.16. In five similar studies where the rations were also enriched in LYS and MET in the close-up ration as well as for the first third of lactation daily milk yield was improved by 5 lbs of milk, 112g of milk protein and milk protein % increased +0.09. In these five trials, daily milk fat yield was also increased by 115g and milk fat % by +0.10. This seemed to indicate very strongly that the principles of balancing rations for MET and LYS should be applied also in the close-up rations to extract maximum benefit during lactation.

AMINO ACID REQUIREMENTS/TARGET FORMULATION LEVELS

At present our knowledge base is not sophisticated enough to determine accurately, individual amino acid requirements based on the traditional factorial approach of estimating a requirement for maintenance, growth, lactation, pregnancy etc. The current accepted and more robust approach is the indirect response curve method proposed first by Rulquin and Verite 1993. This methodology was subsequently used in NRC 2001. The advantage of this method is that the determination of supplies and requirements of individual amino acids are interdependent. Requirements are estimated as a dose response function using the approach established to estimate metabolizable amino acid supplies. Requirements are therefore dependent on and can vary between different formulation systems. To the purist, there can be only one requirement for an animal at a defined physiological status and determined level of production, therefore a more correct terminology to use would be target formulation levels or recommendations, rather than requirements.

In Fig 1. you will see the representation of the dose response curves used to establish the levels of LYS and MET as a % of MP needed to optimize milk protein concentration. Optimums were established at 2.4 and 7.2 as a % of MP for MET and LYS respectively. As intimated earlier these levels cannot be achieved in practice. Particularly on corn grain based rations, it will be difficult to achieve LYS levels higher than 6.7% of MP. Target formulation levels of 6.66 LYS and 2.22 MET as a % of MP have been suggested with respect to the NRC 2001 formulation approach.

It is important to note that MET levels will depend on the level of LYS that can be achieved. The first step is to maximize LYS as a % of MP, then balance the MET to keep a 3.04 to 1 ratio to maximize efficiency of utilization of MP and minimize the wastage of overfeeding MET. These target formulation levels will be somewhat different depending on the formulation system employed. For example, when using CNCPS or CPM Dairy, target formulation levels are suggested at 6.83 and 2.19% of MP. This is because when running the same ration through both models, in general, CNCPS predicts higher levels of LYS in MP compared to NRC. Target LYS formulation levels have to be adjusted accordingly and the optimum LYS to MET ratio will change also. A ratio of 3.12 to 1 is suggested as the optimum to use with CNCPS and CPM Dairy.
Milk protein content responses as a function of metabolizable methionine (MET) and lysine (LYS) concentrations in MP - Page 84 of NRC 2001.

MARGINAL EFFICIENCY

The concept of marginal efficiency is certainly very important when trying to estimate responses on a herd basis to a change in supply of any dietary nutrient. The observed herd marginal efficiency is the average of all the individual responses of each cow in the herd. Each cow will have its own innate capacity to respond, depending on a multitude of factors such as physiological status, intake and stage of lactation.

Thus on a herd basis the response to additional nutrients will be very much, curvilinear in nature and hence the need to take into consideration marginal efficiency. Most of the time when we talk about marginal efficiency it is in relation to the immediate or short term response to the change in dietary supply of a nutrient. On farm this most often corresponds to the time frame for evaluating whether the change has had a positive impact and deciding whether the practice will be continued as part of the mainstream nutrition program. This may be somewhat short sighted as the maximum benefit is often not achieved until at least one complete lactation cycle has been completed for every cow in the herd.

So in the context of amino acid nutrition on a herd basis what marginal efficiencies of utilization do we observe? Let us look at this through the eyes of the new NRC 2001 protein system:

The new NRC 2001 says that after the maintenance requirement is deducted, and any requirement for growth and pregnancy, 67% of the remaining metabolizable protein (MP) is converted into milk protein. By definition if there is a strict limitation to increasing milk protein synthesis caused by one amino acid, then enhancing the metabolizable supply of that amino acid should increase milk protein secretion (g/day) calculated as follows:

Increase in supply of limiting amino acid/
proportion of limiting amino acid in milk protein*0.67.

In the case of a ration limiting in 10g of metabolizable methionine this would mean milk protein can be increased by 10/0.026*0.67=257 g (assumes milk protein contains 2.6% methionine).
When was the last time you observed a response of this nature? This would mean a herd producing 40 kg per cow (90lbs) at 3.0% milk protein could increase daily milk weights by 3.5 kg (7.5lbs) per cow and milk protein % by +0.35. Some individuals within a herd may be able to respond with this order of magnitude but it would be rare in a whole herd to see a dramatic response such as this. When Garthwaite et al 1998 summarized the continuous feeding trials in the literature where metabolizable lysine and methionine supplies were improved over Controls, they identified seven trials where the enriched rations in LYS and MET matched very closely the target levels of LYS and MET as a % of MP, defined earlier. The average increase in milk protein synthesis was 90 g per cow per day (3lbs of milk, 0.1% in milk protein). In all seven trials, methionine was the first limiting amino acid and the marginal efficiency of utilization of methionine for milk protein synthesis was calculated to be 0.26. This is obviously a lot lower than the overall efficiency of utilization of MP (0.67) used in NRC 2001. In fact, on a herd basis, it may be better to be prudent and assume a marginal efficiency for methionine of no more than 20%.

This translates to the rule of thumb - for every supplementary gram of metabolizable methionine, milk protein secretion is increased by 7 g per cow per day. One reason, why the apparent marginal utilization of methionine for milk protein synthesis is so low, is because methionine does not only serve as an amino acid building block for protein synthesis. It has many other roles in the dairy cow which are often loosely referred to as methyl donor effects. Obviously these other functionalities are important in ensuring the well-being of the animal but their quantitative importance is more difficult to estimate.

Lysine on the other hand, only has one role in the body as a building block for protein synthesis - so is the marginal efficiency of utilization of lysine for milk protein synthesis higher? There are few studies in the literature where LYS has been evaluated in a dietary situation where it is strictly the first limiting amino acid and not co-limiting with methionine.

Piepenbrink et al 1999 fed a MET enriched ration, and studied in a dose response manner using a replicated Latin square design the response to increasing supplies of LYS. Milk protein secretion increased in a linear fashion. The optimum response was an extra 173g of milk protein (6lbs milk, +0.2% milk protein) to increasing daily metabolizable lysine supply by 34g - a marginal efficiency of 40%. Likewise, McLaughlin et al 2002 performed a very similar experiment increasing milk protein output by 217g/day (4.5lbs milk, +0.27% milk protein) by enhancing LYS supply by 49.5 g - a marginal efficiency of 35%.

Although care should be taken, not to put too much emphasis on the results of two trials, they do seem to indicate the marginal efficiency is higher for LYS compared to MET. In fact compared to the “MET” studies, these two studies were conducted in dairy cows longer in days in milk and with very short periods of supplementation which would normally be considered to have a tempering influence on the ability to demonstrate optimal responses. Thus in practice in a continual feeding situation, with cows at all stages of lactation a 40% marginal efficiency of utilization would seem to be a cautiously optimistic number to use. What this means is that when LYS is the limiting amino acid for milk protein synthesis, 10 g of extra metabolizable LYS can increase milk protein secretion by 50g per cow per day (10*0.4/0.08). Assumes milk protein contains 8.0% lysine.

What is also of importance to point out is the expression of the milk protein secretion response to enhancing LYS supplies. It appears that there is roughly a 50:50 split between an increase in milk volume and an increase in milk protein % . Again this is different to the
responses observed with MET. In mid lactation cattle, you seldom see any of the response in milk protein secretion being expressed as an increase in milk volume.

**EFFICIENCY OF UTILIZATION OF MP**

What is intrinsic to achieving milk protein responses to extra MET and LYS is the reality that the dairy cow has an oversupply of all the other amino acids. Thus when the missing link is provided, a whole new milk protein molecule can be synthesized. Ideally the ration should be formulated to supply metabolizable, individual essential amino acids in the correct ratios to minimize wastage. When only MP is considered as the entity defining amino acid supplies, there is no estimation of likely limiting amino acids and therefore milk performance is less predictable.

Recently Schwab et al (2004) presented an update, which compared MP, LYS, and MET supplies as predictors of milk volume and milk protein yield. MP supply does an adequate job ($r^2$ of 0.65) of predicting milk volume and a slightly better job of predicting milk protein yield ($r^2$ of 0.74). One would expect the latter to be more closely correlated as both the input and outputs are in units of protein. Compared to MP, MET supply was a better predictor of both milk volume ($r^2$ - 0.76) and milk protein yield ($r^2$ - 0.81). However LYS supply proved to be the best predictor of both milk volume and milk protein yield with $r^2$'s of over 0.90. If there were any remaining doubts, this analysis shows that predictability of milk performance can only be improved by starting to pay attention to at least the first two limiting amino acids. By moving in this direction with our formulation approaches we will be reducing the variation in predicting milk performance not increasing it. By continuing to formulate rations uniquely on a metabolizable protein basis with no consideration for metabolizable LYS and MET, performance will be depressed and less predictable, and milk proteins and milk fats will not be optimized reducing net returns from the sale of milk.

When only relying on MP to estimate amino acid requirements, retrospective calculations show that actual milk yield falls short of MP allowable milk in 90% of situations (NRC 2001). Also using the recent analysis of Schwab 2004, he showed the overall efficiency of utilization of MP for milk protein secretion to be only of the order of 0.64 compared to the NRC book value of 0.67, whereas MP utilization was calculated to be superior to 0.67 when MET and LYS were integrated into the formulation approach. It would seem essential to at least pay a minimum attention to LYS and MET content of MP if you wish to continue to rely on a factor of 0.67 for the conversion of MP to milk protein. As an example, let us consider the impact of a lower efficiency of utilization of MP. For a cow producing 40kg of milk at 3.0% milk protein, if the overall efficiency of MP utilization falls from 0.67 to 0.60, milk protein yield would drop by 10% (120g). 120g loss in milk protein yield equates to 2kg (4.5lbs) less milk with a lower milk protein concentration (-0.15%).

The flip side of the above is that the dairy industry has probably been overfeeding protein for years to ensure dairy cows do receive the amino acids they need but this has been at a cost of using protein very inefficiently. Not only is there an energetic cost to the cow of removing excess N, not to mention potential reproductive problems associated with high circulating N levels (Ferguson and Chalupa, 1989) there is a potential cost looming in terms of disposing of the extra N excreted. Rather than continuing the traditional approach resulting in ration formulations at 18% crude protein or above, integrating a formulation approach to
include LYS and MET will allow rations to be formulated at 16.5 to 17.5% CP without compromising milk yield and still improve milk components.

**SELECTION OF RATION INGREDIENTS**

First and foremost ingredients should be selected to maximize the microbial protein contribution the ration can make. Microbial protein has an excellent profile of amino acids and the lysine and methionine content closely matches that found in milk protein. Fermentable carbohydrate will be the driver to maximize microbial protein synthesis. So feeding a good balance of readily fermentable sources with highly digestible NDF sources should be a first priority. Obviously an adequate quantity of rumen degradable protein (RDP) needs to be fed to ensure the rumen fermentable carbohydrate is effectively transformed into microbial protein. Schwab et al 2003 suggests RDP should represent at least 10.5 % of DM. A suggested target objective would be that microbial protein should represent at least 50 % of MP supply. The remaining MP will have to come from rumen undegradable protein (RUP) sources. All RUP sources have lower concentrations of either LYS or MET and more often both compared to milk protein. The success of employing amino acid formulation principles resides in careful selection of raw materials that can truly help increase LYS and MET supplies. Raw materials and protected amino acid products with ‘WISHFUL THINKING’ values for MET and LYS should not be used – they only discredit the use of the sound principles of amino acid formulation.

Blood meal has the greatest potential to elevate LYS levels when included in a ration due to its high CP, RUP and lysine content of RUP such that with a 1lb inclusion, daily LYS supply can be improved by more than 20g. However care should be taken when sourcing blood meal and blended products to ensure the product is consistent and lives up to expectations. Fishmeal, although not as high in lysine as blood meal, is richer in methionine and provides a balanced source of both amino acids, but the same precautions should be taken when sourcing as for blood meal. Soybean meal and protected soya products also have higher than average lysine contents (~6.2% of CP) and their incorporation in the ration can be very helpful to meeting target LYS concentrations in MP. The inclusion of corn distillers and brewers grains should be minimized as they are low in lysine and make reaching target LYS levels extremely challenging.

**ROLE OF RUMEN PROTECTED METHIONINE**

Rumen protected methionines are not feed additives but are feed ingredients and should be used in feed formulation accordingly. They are a potential concentrated source of metabolizable methionine and should be offered along with the conventional feed ingredients available on farm to best cost rations to meet target ration metabolizable LYS and MET levels. Obviously because they are potentially concentrated sources of MET, an accurate assessment of the MET contributions is needed of the technologies available commercially so that these products can be used appropriately and to maximum advantage in dairy rations.

Schwab and Ordway 2003 gave an overview of the technologies currently on offer and the different methodologies that have been used to assess their MET contributions. In many studies, Smartamine™ M has been used as the reference product against which other technologies are measured. Smartamine™ M is estimated to provide 600g/kg as fed of MET.
Mepron M85® has proven to be the next best technology and depending on the study has been shown to provide 200 to 300 g/kg as fed of MET (Berthiaume et al 2000, Blum et al 1999, Olley et al 2004, Overton et al 1996, Robert et al 1997). A recent first study (Olley et al 2004) would suggest Met-Plus™ provides around 200 g/kg of MET as fed. However Alimet® or Rhodimet™ AT 88, both sources of hydroxymethyl butanoic acid (HMB) have now been shown to be negligible sources of MET (Schwab and Ordway 2003). At best they only provide < 50g/kg of MET as fed. However Robert et al (2002), Graulet et al (2004), and Noziere et al (2004) have shown that by esterifying HMB with isopropanol, this slows the normal rapid degradation of HMB by the rumen microflora and facilitates absorption across the rumen wall. The net result is that the isopropyl ester of HMB (MetaSmart™) has been shown to provide 370 g/kg as fed of MET. It may not have the same payload as Smartamine™ M, but has the big advantage of being pelletable, which is not feasible with any of the encapsulated methionine technologies (Smartamine™ M, Mepron M85®, Met-Plus™).

It costs around 1.5 cents per g of MET for any “bona fide” technology. In dairy rations, a rumen protected methionine source would be best costed in, to provide 5 to 10 g of MET, in order to ensure a correct balance between LYS and MET can be achieved. If we use our marginal response “rule of thumb” of 7 g of milk protein for every additional g of MET, then in a ration needing 10g of additional MET, milk protein yield would increase by 70g per cow per day. If we take milk protein paid at $2/lb ($4.40/kg) this would increase milk income by 30 cents per cow per day. Typically there would also be a small fat response such that gross revenue would increase 40 to 50 cents per cow per day. Also part of the protected amino acid ingredient cost would be offset by reducing the amounts (2 to 4%) of other protein sources in the ration to take advantage of improving overall MP utilization.

ROLE OF HMB

If Alimet® or Rhodimet™ AT 88 are not important direct sources of MET, what is their mode of action to improve milk performance? HMB has been shown to have positive effects on milk fat in approximately half the published studies, and in certain studies a large effect on milk volume (Rode et al 1997, Overton 2002), but milk protein % has been seldomly improved.

HMB has been intimated to have effects on rumen volatile fatty acid (VFA) patterns, fibre digestion, and efficiency of microbial protein synthesis, microbial lipid synthesis, and protozoa populations. However a clear mechanism of action has still to be elucidated. Nevertheless the effects do appear to be dose dependent (Sloan et al 2000, Overton 2002). 0.11 HMB as a % of DM intake appears to give the optimum result.
WINNING COMBINATION

As the effects of amino acid formulation are predominantly on milk protein and the effects of HMB are predominantly on milk fat, the two approaches can be employed together in practical feeding programs to enhance milk volume and components. Nootsger and St. Pierre 2003 demonstrated, in their production study, four important elements that can have a marked impact on milk performance.

1. MP level in the ration
2. Intestinal digestibility of RUP sources in the ration
3. Balancing rations for LYS and MET
4. Inclusion of HMB

They compared four rations. The control ration was formulated to be adequate in MP using conventional forages and concentrate ingredients, using principally porcine meat meal as the source of RUP. The second ration was formulated to the same target formulation constraints as the control ration, but a selected highly intestinally digestible animal protein source replaced the porcine meat meal. These two rations were formulated to contain 18.3% crude protein. In the third ration, the same ingredients were used as in Ration 2 but RUP and thus MP concentrations were lowered such that the ration was formulated at 16.9% CP. Both rations 2 and 3 were found to have LYS concentrations approaching 6.6% of MP but very inadequate levels of MET (<1.8% of MP). In ration 4, the target was to add a protected methionine source to Ration 3 and have a ration more balanced for LYS and MET. The only other change in ration 4 was the inclusion of HMB at 0.11% of DMI to ensure optimum microbial protein synthesis. The results are shown in Table 1.

The importance of intestinal digestibility of RUP sources was well demonstrated in this trial. Substituting the selected animal protein for porcine meat resulted in 5.4 kg more milk albeit that part of this effect was due to a 1.6 kg increase in DMI. However economizing on protein inputs, through lowering the CP of the ration to 16.9% by decreasing RUP and MP lost 3.3 kg of the 5.4kg gain. This was reversed by balancing the low CP ration for LYS and MET and including HMB. In fact not only was the volume of milk produced highest on the 4th ration but milk components were also highest. 40g more milk fat and 60g more milk protein was exported compared to Ration 2 the next best treatment. The retrospective calculation of MP allowable milk for each treatment again shows clearly the superior efficiency of dietary protein utilization on the amino acid balanced ration. NRC, 2001, would only predict that there was sufficient MP in the diet to support a daily yield of 39.5 kg whereas the cows on this treatment achieved 46.6 kg. The decreased MUNs and the calculated very negative MP balance reflect an apparent efficiency of utilization of MP superior to the assumed average of 0.67 and not a shortage in MP supply relative to requirements. Similar results were achieved by Sylvester et al. 2003. In their trial, MetaSmart™ replaced Smartamine™ M as the concentrated source of MET. The feeding of the ration balanced for LYS and MET and formulated to contain 0.11% rumen available HMB increased daily milk production by 3.5kg, milk fat by 230g and milk protein by 159 g.
Table 1. Least square means for performance measures for diets that vary in CP and digestibility of RUP (Sylvester et al, 2003)

<table>
<thead>
<tr>
<th>Ration</th>
<th>Dry Matter intake (kg/day)</th>
<th>Milk (kg/day)</th>
<th>MP Allowable Milk</th>
<th>Fat (kg/day)</th>
<th>Protein (kg/day)</th>
<th>Fat %</th>
<th>Protein %</th>
<th>MUN (mg/dL)</th>
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<tr>
<td>1</td>
<td>21.7</td>
<td>40.8</td>
<td>37.2</td>
<td>1.39</td>
<td>2.95</td>
<td>3.42</td>
<td>2.95</td>
<td>16.82</td>
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<td>48.9</td>
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<td>3.64</td>
<td>3.64</td>
<td>17.28</td>
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<td>3</td>
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<td>42.9</td>
<td>39.9</td>
<td>1.57</td>
<td>2.99</td>
<td>3.66</td>
<td>3.66</td>
<td>14.30</td>
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<tr>
<td>4</td>
<td>23.6</td>
<td>46.6</td>
<td>39.5</td>
<td>1.71</td>
<td>3.09</td>
<td>3.73</td>
<td>3.73</td>
<td>13.47</td>
</tr>
<tr>
<td>Sig.</td>
<td>P&lt;0.04</td>
<td>P&lt;0.001</td>
<td></td>
<td>P&lt;0.001</td>
<td>P&lt;0.002</td>
<td></td>
<td></td>
<td>P&lt;0.001</td>
</tr>
</tbody>
</table>

1 control diet with porcine meat meal as the source of supplemental RUP
2 same level of RUP as control but with highly digestible supplemental RUP source
3 highly digestible supplemental RUP source with overall RUP decreased
4 same as Ration 3 but enriched in MET and including HMB

AMINO ACID FORMULATION ON FARM

So armed with the previously described principles and rules of thumb, what strategies can be applied on farm to improve the nutrition of the dairy cow and the economic return to the dairy producer. Table 2 illustrates three alternatives.

Scenario 1 - A herd is not performing according to expectations - both volume and milk components are disappointing. In this case, the strategy would be to at least maintain the current MP concentration in the ration, improve LYS and MET to the maximum practical target levels in order to boost both yield and components. This may entail increasing feed costs by 20 to 40 cents per cow per day but potential improvements in income over feed costs can be as much as 40 to 100 cents per cow per day.

Scenario 2 - A herd is performing more than adequately in terms of yield but milk components are disappointing and dietary protein inputs are high. In this case we can use the tool of improving efficiency of utilization of MP by formulating to meet the target levels of LYS and MET to decrease MP(RUP) levels in the ration, at least maintain milk yield and still improve components. The additional ration cost will be a trade off between the cost to improve the levels of LYS and MET in MP and the savings from reducing the amount of RUP needed in the ration.

Scenario 3 - The only expectation is to feed a “better” ration for the same feed cost. In this context the levels of LYS and MET can often still be improved moderately through reformulation - the difference still being important enough to get some improvement in milk protein %.
Table 2. Estimated responses to employing different ration formulation strategies.

<table>
<thead>
<tr>
<th>∆</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milk Yield</strong> lbs</td>
<td>+4 to 8</td>
<td>+0 to 2</td>
<td>+0 to 1</td>
</tr>
<tr>
<td><strong>Milk Protein %</strong></td>
<td>+0.1 to 0.3</td>
<td>+0.1 to 0.3</td>
<td>&lt; +0.1</td>
</tr>
<tr>
<td><strong>Feed Costs Cents/day</strong></td>
<td>+20 to 40</td>
<td>+5 to 20</td>
<td>0</td>
</tr>
<tr>
<td><strong>IOFC - cents per cow per day</strong></td>
<td>+40 to 100</td>
<td>+20 to 60</td>
<td>+10 to 20</td>
</tr>
</tbody>
</table>

So once you take the plunge to reformulate your rations in terms of LYS and MET - how do you know if it has worked? Typically when a ration is reformulated to be balanced for LYS and MET a major increase in milk protein % will be clearly visible in the days that follow the ration change (Brunschwig and Augeard, 1994). Thereafter, if cows are kept on a balanced amino acid ration program, the increase in milk protein % will become even more pronounced over time. For example, if a herd has an immediate response of +0.1% in milk protein and a good amino acid balanced ration is fed continuously over the following 12 months then the rolling herd milk protein average should increase by as much as +0.2 %. Increases in milk protein % are the easiest indicator of a change in ration formulation being successful. Nevertheless the economic advantage will be primarily determined by the increase in milk protein yield, therefore effects on milk volume are important as well. As indicated earlier the largest milk volume responses are observed in early lactation and are also related to the degree of improvement in LYS supply. Thus depending on the proportion of early lactation cows in the herd, an estimate can be made of the likely evolution in milk volume to the change in ration formulation.

**SUMMARY**

Individual amino acid formulation is the next logical evolution towards satisfying dairy cow “protein” requirements. When consideration is given to metabolizable LYS and MET concentrations in MP, more cost effective rations can be formulated, and better, more predictable, milk performance (volume and components) achieved. Continuing to formulate rations uniquely on the principles of RUP and RDP without paying any attention to amino acid balance principles will lead to more variable milk yields, lower milk protein and fat %’s and lower income over feed costs.
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