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Amino Acid Feeding Concepts for Dairy Rations

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Since the publication of the NRC 2001, there has been renewed interest to formulate dairy diets not only to meet conventional "protein" requirements but also to balance the ration for at least the first two limiting amino acids – methionine and lysine. The rigorous approach adopted in developing the amino acid supply sub-model and the accompanying amino acid requirement recommendations has solidified the principles of "ideal protein" into a robust system that works. Dairy diets can now be formulated to ensure a more efficient use of dietary protein while optimizing milk yield and components – particularly milk protein. This in itself presents the producer with the opportunity to improve Income over Feed cost (IOFC) through producing more of a more valuable product for a marginal increase in feed cost. However the "hidden" benefits in some cases may be contributing as much, if not more to the profitability of the dairy enterprise. Feeding diets balanced for amino acids have also been shown to play a preventative role for certain metabolic disorders, positively influence energy balance and consequently improve reproductive performance.

REVIEW OF THE BENEFITS 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.

ENHANCED MILK PERFORMANCE

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 showed that the principles of balancing rations for MET and LYS should also be applied in the close-up rations to extract maximum benefit during lactation.

IMPROVED EFFICIENCY OF UTILIZATION OF MP

This is the factor that is fundamental to achieving the benefit of balancing rations for MET and LYS. In essence 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, reducing the surplus of the other amino acids and by definition improving the efficiency of utilization of MP. Further, 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). In a recent analysis, Schwab 2004 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 balancing for 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 be predicted to 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 studies of Piepenbrink et al 1999 and McLaughlin et al 2002 demonstrate this important facet of balancing rations for amino acids. 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. The efficiency of utilization of MP for milk protein synthesis was only 0.53 for the imbalanced ration without any supplemental LYS supplementation. Intakes did not change, therefore at the optimum level of LYS supplementation, the efficiency of utilization of MP was improved to 0.67. 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 increasing LYS supply by 49.5 g.

This would suggest that 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 likely to be less predictable because of this. 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^2s of over 0.90. 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.

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.

FEED EFFICIENCY

Not only is the efficiency of MP utilization improved when rations are balanced for LYS and MET, but so is overall feed efficiency. Hutjens 2005 has proposed a measurement that can be calculated and used as an indicator of feed efficiency for evaluative purposes. Normally this is expressed as lbs of 3.5% fat-corrected milk per pound of feed dry matter consumed. However he proposes another indicator that corrects for protein as well as fat which is more appropriate for consideration where the effects on milk protein yield are also expected to be important :

3.5% fat and protein corrected milk (lb) = (12.82 x lb fat) + (7.13 x lb protein) + (0.323 x lb of milk)

For the seven early lactation milk performance trials cited earlier from Garthwaite et al 1998 the average improvement in feed efficiency was calculated to be +0.08 (1.93 vs 1.85).

REDUCTION IN METABOLIC DISORDERS

High feed efficiency in itself may not be a good indicator of a healthy ration if it is at the expense of mobilizing energy reserves too rapidly, which could lead to metabolic disorders and delayed or impaired reproduction. Nevertheless when rations are balanced for lysine and methionine, due to the improved efficiency of use of MP, less 'energy' is needed to eliminate surplus amino acid N as urea, allowing energy to be put to a more productive use. A further reason that could help explain the improvement in feed efficiency and in particular energy status may be associated with methionine's other roles in metabolism, rather than simply as a building block for milk protein synthesis.

Methionine has long been advocated as having a favourable role on hepatic metabolism through its capacity as a methyl donor. A series of trials (Bauchart et al 1998) illustrate more clearly the roles that methionine plays in hepatic metabolism. Methionine plays a key role in assuring the synthesis of apoprotein B, an essential component in the formation of the very low density lipoprotein (VLDL) complex which is responsible for evacuating triglycerides from the liver to peripheral tissues. One study that illustrates this mode of action of methionine and lysine was realised by Durand et al 1992. They measured across the liver, the net appearance or disappearance of VLDLs, before, after and during portal infusion of extra lysine and methionine. Before and after the infusions there was a negative balance whereas during the infusion a positive balance was obtained. It is hypothesized that this may be due to methionine acting at three different levels to predispose these effects. Firstly, methionine is an essential building block for the formation of apoprotein B. Secondly methionine appears to be involved in the gene transcription and or translation of mRNA for apoprotein B synthesis. Thirdly methionine may also act as a methyl donor to favour lecithin synthesis which is essential for the elaboration of the hydrophilic envelope of hepatic VLDL. The net effect is a reduction in the risks of fat infiltration of the liver which predispose problems such as fatty liver and ketosis.

Two lactation studies were subsequently carried out over the first 4 to 6 weeks of lactation. Cows were fed to be fat at calving and then fed an energy restricted diet at the beginning of lactation. Half the cows were fed supplementary LYS and or MET. The improvements in performance were dramatic - an extra 2.5 kgs of milk and an increase of 2.5 g/kg in milk protein content – the combined increase in milk component yield was over 250 g/day. In the second trial the milk performance improvements were also associated with a large reduction in circulating ketone body levels in the second week of lactation confirming that enhancing the supply of MET and LYS can help reduce metabolic disorders.

IMPROVED REPRODUCTION

Conventional wisdom would indicate that any ration manipulation that can help minimize metabolic disorders and improve energy status of cows in early lactation should also have a potential to positively influence reproductive parameters (Santos et al 2005). Robert et al 1996 observed a better uterine involution (% of animals whose uterus has regressed to normal size at 45 days post calving). This was associated with a reduced number of inseminations needed per conception but neither effect was significant. They also measured milk progesterone levels every 3 days for the first 112 days of lactation to follow the cyclicity. They were able to show that the cows receiving a ration balanced for LYS and MET had higher progesterone levels pre successful ovulation than control animals. This is considered to potentiate a strong ovulation. Also during the 5 days after insemination progesterone levels were also higher which is often regarded as a positive factor for the embryo to successfully implant. Thiaucourt 1996 was able to demonstrate in field trials (53 farms, 2000 cows) that the feeding of a ration formulated to be rich in LYS and MET, improved timing to first insemination and calving interval by 5 days ($P < 0.1$).

The other avenue through which ration amino acid balancing should be able to positively influence reproductive function is by facilitating a reduction in high circulating levels of blood urea through the lowering of ration CP content without hurting milk performance. There is a generally accepted negative association between plasma, serum, and milk urea N and conception rates in high producing lactating cows (Butler et al 1996, Ferguson et al 1993, Santos 2005). Elrod et al 1993 found that by overfeeding RUP or RDP in the diet, uterine pH was reduced on day 7 of the estrous cycle of heifers and in the case of overfeeding RDP this was associated with a much lower conception rate.

A ROLE IN IMMUNE RESPONSE?

The role of MET and LYS in immune function is still somewhat speculative in dairy cows. It has been shown in chicks, that sulphur amino acid status is an important determinant of the immune response to a Sheep Red Blood Cell challenge. Similarly in newly arrived, "stressed" feedlot, steers, Spears et al 1996 showed that fortifying the diets with LYS and MET reduced rectal temperatures compared to Controls after inoculation with IBR intranasally followed seven days later with an injection of pig red blood cells. This was accompanied by an improved humoral response as indicated by a higher IgM titer.

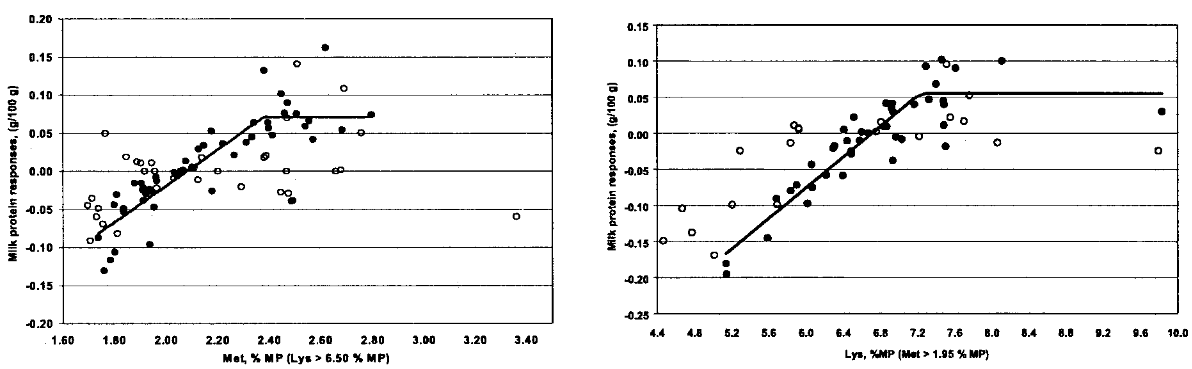
In dairy cows, there is only some indirect evidence that balancing rations for LYS and MET may be positively impacting the immune system. In the field study of Thiaucourt 1996, involving 2000 cows across 56 farms, the classical improvements in milk protein % (+0.13), and improved milk production in early lactation (+3.5lbs/day) were observed when feeding rations balanced for LYS and MET. Because it was available Somatic cell count was also tracked. He found somatic cell count was reduced by 50,000/ml. He speculated a series of factors that could have contributed to this phenomenon – the general immune response is improved if animals have an improved energy status, the extra supply of methionine increases circulating taurine levels thought to be important in maintenance of the stability of cell membranes and in anti-oxidant reactions, the synthesis of the keratin ring, a protein rich in cysteine, at the extremity of the teat duct may be improved, enhancing the protection against intra-mammary infection.

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. Thus practical 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 prevent the unnecessary overfeeding of 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.



Figures 1a and 1b - Milk protein content responses as a function of metabolizable methionine (MET) and lysine (LYS) concentrations in MP – Page 84 of NRC 2001.

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 to be fed at a single dosage rate irrespective of ration composition. They are feed ingredients and should be formulated into feed accordingly. They are concentrated sources 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 real MET contributions of the technologies available commercially is needed 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 available 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 (MetaSmart), 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 1.7 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 that a correct balance between LYS and MET can be achieved. If we use a marginal response "rule of thumb" of 7 g of milk protein for every additional g of MET (Sloan, 2005), 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 $2.50/lb ($5.50/kg) this would increase milk income by 38 cents per cow per day. Typically there would also be a small fat response such that gross revenue would increase 50 to 60 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.

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ROLE OF HMB

As indicated earlier, maximizing the microbial protein contribution is a first priority when balancing a ration for LYS and MET. Although the HMB in Alimet® or Rhodimet™ AT 88 is a negligible source of MET, it has been shown to enhance non ammonia N flows in continuous culture fermenters through improving the efficiency of microbial protein synthesis (Sloan et al 2000). Feeding HMB thus ensures the concentration of lysine in duodenal flows of protein is maximized and also gives a further opportunity to economize the level of protein in the ration. The benefit of incorporating HMB in the ration is mainly observed on milk fat (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.

The role that HMB plays in the rumen is complex and a precise mode of action has not been validated. Nevertheless HMB has been intimated to have effects on rumen volatile fatty acid (VFA) patterns, fibre digestion, microbial lipid synthesis, and protozoa populations as well as the efficiency of microbial protein synthesis. The effects do appear to be dose dependent (Sloan et al 2000, Overton 2002). 0.10 HMB as a % of DM intake appears to give the optimum result.

WINNING COMBINATION – THE BEST FORMULATION OPTION

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. We tend to refer to this as the "Winning Combination".

Noftsger 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 for its ruminal action

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 0.10% of DMI to ensure optimum microbial protein synthesis. The results are shown in Table 1.

Table 1. Least square means for performance measures for diets that vary in CP, digestibility of RUP, and LYS and MET concentrations

	Ration1	Ration 2	Ration 3	Ration 4	Sig.
Dry Matter intake (kg/day)	21.7	23.3	23.2	23.6	P<0.04
Milk (kg/day)	40.8	46.2	42.9	46.6	P<0.001
MP Allowable Milk	***37.2***	***48.9***	***39.9***	***39.5***	
Fat (kg/day)	1.39	1.67	1.57	1.71	P<0.001
Protein (kg/day)	1.20	1.38	1.28	1.44	P<0.001
Fat %	3.42	3.64	3.66	3.73	P<0.004
Protein %	2.95	2.98	2.99	3.09	P<0.002
MUN (mg/dL)	16.82	17.28	14.30	13.47	P<0.001

[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

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 4^{th} ration but milk components were also highest. 40gs 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 improvements in milk performance and feed protein utilization were also achieved by Sylvester et al 2003 (Table 2). In their trial, MetaSmart™ replaced Smartamine™ M as the concentrated source of MET while also providing ruminal available HMB. They showed that feeding HMB alone gave an apparent positive effect on milk volume and fat %. The feeding of a ration balanced for LYS and MET including MetaSmart™ improved significantly milk volume and components but the best results (daily milk production was increased by 3.5kg, milk fat by 230g and milk protein by 159 g) were obtained where additional ruminal HMB was added to increase ration HMB concentration to 0.11%.

Table 2. Effect of HMB and HMBi supplementation of a LYS adequate diet on milk production and composition.

	Control	+HMB	+HMBi	+HMBi/HMB	Sig.(HMBi)
Dry matter intake (kg/day)	22.7	22.8	23.5	23.0	NS
Milk (kg/day)	39.8	40.7	42.3	43.2	P<0.001
Fat (kg/day)	1.44	1.55	1.65	1.67	P<0.001
Protein (kg/day)	1.10	1.16	1.23	1.26	P<0.001
Fat %	3.61	3.76	3.82	3.86	NS
Protein %	2.81	2.88	2.97	2.95	P<0.001
MUN (mg/dL)	12.6	13.6	12.0	11.3	P<0.01

AMINO ACID FORMULATION ON FARM

So armed with this "knowledge" of the principles of amino acid nutrition, what strategies can be applied on farm to improve the nutrition of the dairy cow and the economic return to the dairy producer. Table 3 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 and ensure a rumen available HMB concentration of 0.10% 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 and incorporating HMB 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 3. Estimated responses to employing different ration formulation strategies.

Δ	Scenario 1 Improve volume and components	Scenario 2 Improve components	Scenario 3 Better ration - same cost
Milk Yield lbs	+4 to 8	+0 to 2	+0 to 1
Milk Protein %	+0.1 to 0.3	+0.1 to 0.3	< +0.1
Milk Fat %	+0.1 to 0.4	+0.1 to 0.4	< +0.1
Feed Costs cents/day	+20 to 40	+5 to 20	0
IOFC – cents per cow per day	+40 to 100	+20 to 60	+10 to 20

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). It will take up to a month to see the full effects on milk fat %. 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 and fat 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 more accurately satisfying dairy cow protein requirements. When consideration is given to metabolizable LYS and MET concentrations in MP and supplying HMB to the rumen, more cost effective rations can be formulated, and better, more predictable, milk performance (volume and components) achieved.

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