30th ANNIVERSARY
Amino Acid Balancing

HANDBOOK

AMINO ACID BALANCING

A KEY TO LIFETIME PERFORMANCE

ADISSEO
A Bluestar Company

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PREFACE

This handbook shares the practical benefits of amino acid (AA) balancing as realized through 30 years of Adisseo research and experience. Guidelines on AA formulation are presented for the important stages of the lactation cycle and for their positive consequences on sustainability and lifetime performance.

The Ph.D. work of Professor Emeritus Chuck Schwab, University of New Hampshire, demonstrated in the mid-1970s the principle that individual AAs limit dairy cow performance. Nevertheless, it has taken half a century for the dairy industry to start to adopt in practice the concept of AA balancing for the benefit of the dairy producer.

The first practical milestone was the publication in France in 1993 of a dairy AA formulation system by H. Rulquin and R. Vérité titled "Amino acid nutrition of dairy cows. Productive effects and animal requirements." in the publication *Recent Advances in Animal Nutrition*, pages 55–77. In it, each feed ingredient was assigned a value for metabolizable lysine and methionine based on the ingredient's characteristics – fermentable organic matter as a predictor of microbial protein supply, protein degradability and intestinal digestibility, and methionine and lysine content.

A pragmatic approach was taken to determine requirements for methionine (MET) and lysine (LYS). Optimum MET and LYS concentrations in metabolizable protein (MP) were determined by the indirect dose

response technique. This approach was later adopted by the 2001 National Research Council (NRC 2001). However, bypass protein was no longer a fixed value by ingredient but dependent on passage rate and, thus, dry matter intake.

In the last 20 years, the Cornell Net Carbohydrate and Protein System (CNCPS) has developed its own approach to determining AA supplies and requirements. Important improvements with respect to previous formulation systems are recognition that AA requirements should be linked to metabolizable energy (ME) supply, and the integration of a rumen submodel to calculate AA flows from not only bacteria but also protozoa. These will be seen in the forthcoming Version 7 of the CNCPS model.

There are several systems including that of The National Academies of Science, Engineering and Medicine (NASEM 2021). In other regions of the world, other approaches are used. Yet, all are converging on the importance of supplying all the required nutrients including AA.

The rationing tools are there to implement AA balancing effectively. The vocation of Adisseo is to provide advice to nutritionists on how to implement AA balancing solutions to maintain and improve the profitability of their dairy producers' operations in the face of new challenges in the dairy industry.

B K Sloan

Dr. Brian Sloan

Business Director — Protected Amino Acids
Adisseo

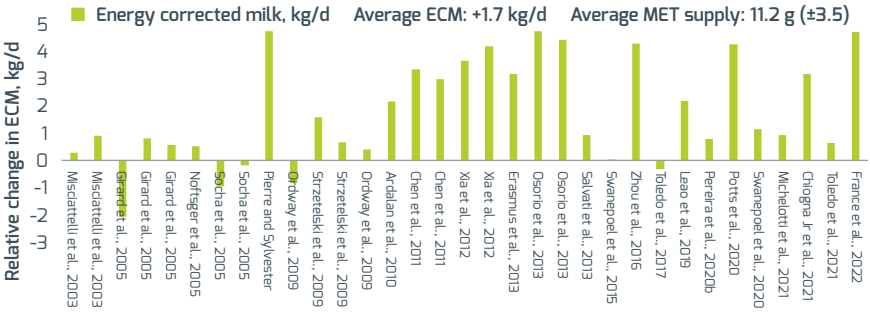
AMINO ACIDS – ESSENTIAL NUTRIENTS

For Milk Performance

The dairy animal needs AA as building blocks for the synthesis of all the proteins required by the body for optimal function and for secretion of milk protein. This ranges from the synthesis of enzymes involved in metabolism to the production of proteins in muscle and milk. Therefore, it is no surprise that dairy cows fed AA balanced rations are healthier but also maximize milk yield and energy corrected milk (ECM) due to the enhanced secretion of both milk protein and milk fat.

AA balancing promotes energy corrected milk

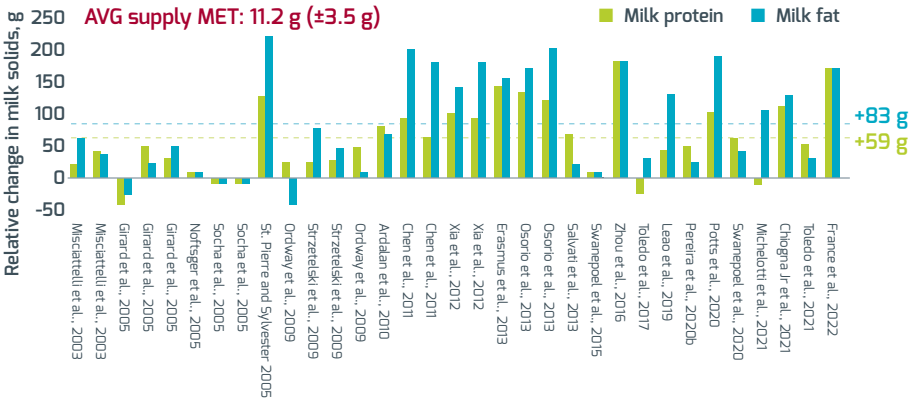
Smartamine® M and MetaSmart®: 25 studies, 33 treatments



Energy corrected milk yield equation: (0.327 = milk yield (kg)) + (12.95 = milk fat (kg)) + (7.66 = milk protein (kg))
Dairy Record Management Services, in *DHI Glossary*, DFMS; Ames, IA, USA 2010

Amino acid balancing increases both milk protein and fat

Smartamine® M and MetaSmart®: 25 studies, 33 treatments



+ 83 g
Milk fat

+ 59 g
Milk protein

A compilation of the 25 trials (33 treatments) initiated by Adisseo in the past 30 years shows an average improvement in daily ECM of 1.7 kgs per day, +83 g (0.16%) in milk fat and +59 g (0.13%) in milk protein. In these trials, Control rations adequate in LYS (25 treatments) were enriched with MET (Smartamine® M or MetaSmart®) or in two trials with Smartamine® ML to achieve minimum target levels of LYS and MET considered necessary to be AA balanced.

+ 0.16%
Milk fat

+ 0.13%
Milk protein

The improvements in milk protein secretion to AA balancing validate previous estimations. More importantly this confirms that milk fat is increased at least to the same extent as milk protein when AA balanced rations are fed. The underlying mechanisms for this positive effect on milk fat are coming to light from ongoing research at the cellular level.

AMINO ACIDS – ESSENTIAL NUTRIENTS

For Metabolic Health and Transition Cow Performance

Dairy cows are particularly sensitive to AA supplies in the pre- and post-fresh periods of lactation. Enriching rations with MET has increased ECM, milk fat and milk protein by 2.2 kgs, 120 g and 90 g, respectively, during the first four weeks after calving, partially due to facilitating an increase in feed intake (> 1 kg per day).

Enhancing the concentration of MET in pre-fresh rations prepares the dairy animal for the onset of lactation. Her antioxidant status, inflammation and immune function are improved, helping to stave off metabolic challenges, and inflammation immediately postpartum. Typically, the incidence of post-calving disorders such as clinical and subclinical ketosis and metritis is less frequent. Such improvements in health allow more energy to be put toward milk rather than fighting inflammation. This contributes to increased production with MET as described earlier.

Continuing the practice of AA balancing and reinforcing MET levels immediately post calving, maintains the robust metabolic and immune status described above. In addition to those effects, liver function is positively affected. In the liver, MET helps to improve hepatic function through antioxidant production.

The higher levels of circulating MET also ensure the necessary availability for managing the flux of mobilized fatty acids (FA). Greater MET provides the limiting amino acid for both apoprotein synthesis and the structurally important phosphatidylcholine, the essential components for formation of very-low-density lipoproteins (VLDL). VLDLs are critical for evacuating the liver of the mobilized FAs and moving them toward the mammary gland for milk fat synthesis. Concomitantly, dry matter intake (DMI) increases rapidly, supporting nutrient demand to drive high peak milk yield and sustainable lactation performance.

It is not only during the transition period where enhancing MET supply may reduce stressors. During periods of heat stress, enhancing MET supply improved biomarkers of cellular damage, oxidative stress and metabolism with a favorable consequence on DMI, milk yield and components. Moreover, MET has a protective effect on mammary cells during heat stress which allows dairy cows to better handle the negative effects of heat stress on metabolism, health and production.

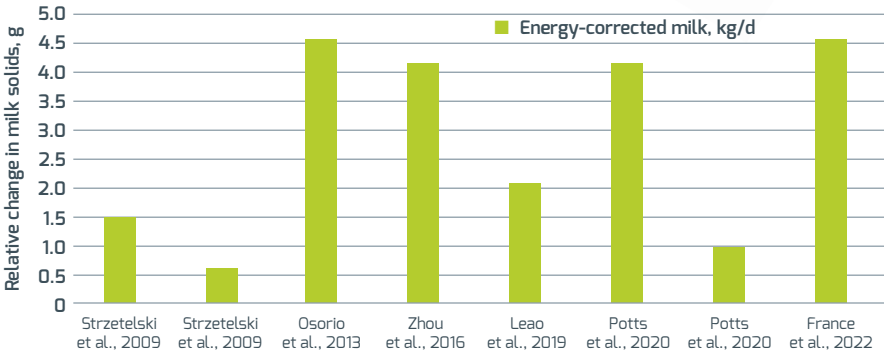
Large immediate benefits on milk performance to providing supplementary MET during the transition period

+ 89 g/d
Milk protein

+ 122.5 g/d
Milk fat

Smartamine® M and MetaSmart®: 8 transition cow studies

ECM = +2.8 kg/d (close-up + fresh cows) DMI = +1.1 kg



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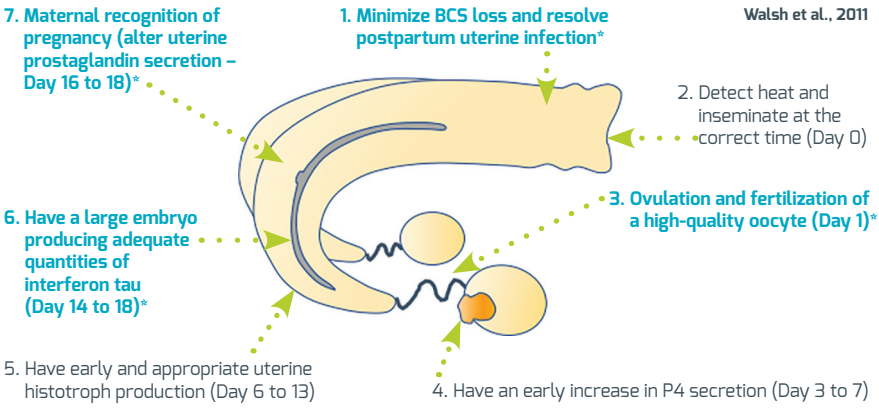
AMINO ACIDS – ESSENTIAL NUTRIENTS

For Reproductive Performance and Reducing Involuntary Culling

Successful reproduction for the next cycle starts even before the cow has calved. For a cow that will be inseminated 70 to 90 days postpartum the maturation of the oocyte commences 30 to 50 days before calving. The dairy cow must effectively involute post calving to have a uterus receptive for implantation of an embryo.

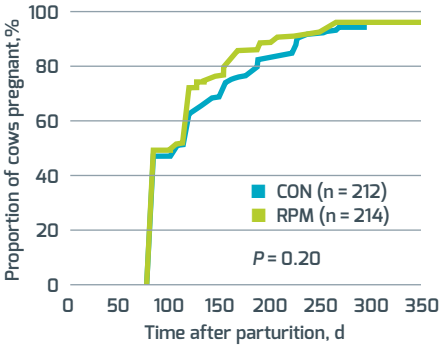
Factors affecting pregnancy in dairy cows



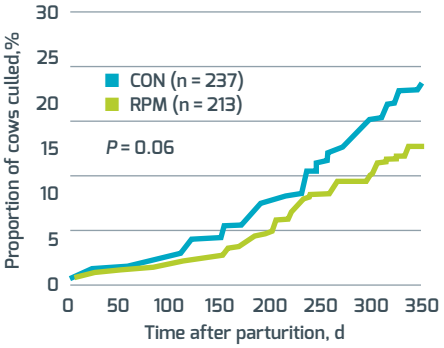
* Affected by methionine

Cows fed methionine during pre-partum to 112 DIM improved health and reproduction status

Time to pregnancy for multiparous cows



Culling of multiparious cows after parturition



Toledo et al., 2023

MET intervenes at several key stages of the reproduction cycle.

- **Follicle quality:** more estradiol and better size
- **Better uterine environment:** less polymorphonuclear neutrophils (PMN)/inflammation, more lipids/energy as nutrient for the embryo
- **Embryo composition:** more lipid, bigger size
- **Pregnancy recognition:** increase concentration of interferon tau (embryo size)

In cows served to natural estrus, heats commence earlier and conception rates are improved. Where OvSynch programs are used, although first service returns are not noticeably improved above the already high rate observed with TAI programs, embryonic mortality can be reduced by half. Also, cows fed AA balanced diets conceived sooner with subsequent inseminations, such that the calving interval was reduced by more than 10 days and a higher percentage of cows remained in the herd for the subsequent lactation.

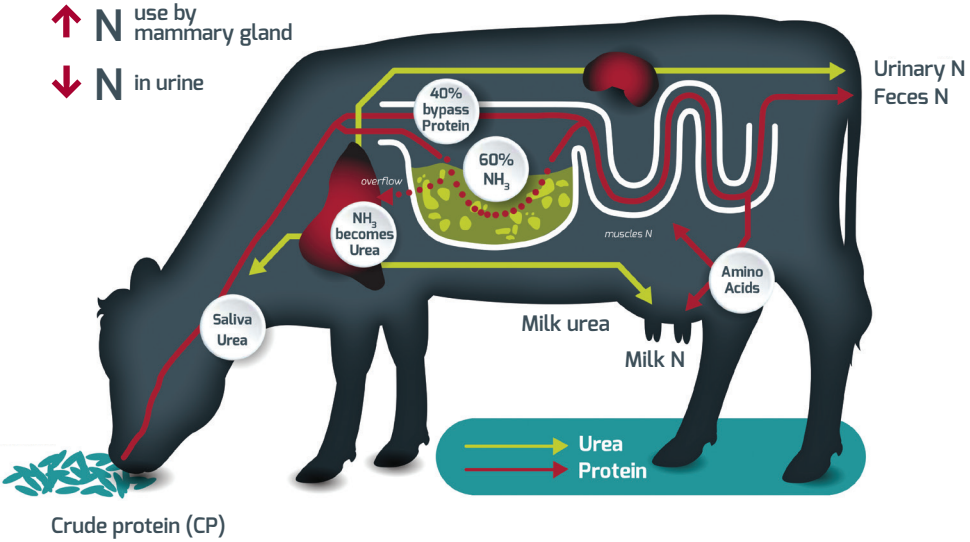
AMINO ACIDS – ESSENTIAL NUTRIENTS

For Nitrogen Utilization and Sustainable Dairying

To overcome the complexities of the ruminant digestive system, nitrogen (N) has continued to be overfed in dairy rations. Typically, only 25% of ingested N is transformed into milk protein. At the rumen level, there is a fear to limiting the rumen degradable protein (RDP) supply and negatively impacting carbohydrate digestion. This is compounded by not dialing in the minimal bypass protein of ideal AA composition needed to complement microbial protein supply.

The days of overfeeding protein as an acceptable practice are finished. Fortunately, our knowledge of AA balancing has progressed such that N inputs can be reduced by up to 10% and the efficiency of N utilization can be increased to over 35% (40% improvement) without compromising milk performance. This minimizes the impact on the environment (water quality, eutrophication…) and reduces the carbon footprint. For every one point reduction in ration CP content through AA balancing, the carbon footprint of dairies is reduced by about 10%.

Nitrogen flow through the cow



AMINO ACIDS

Requirements and Formulation Recommendations – View CNCPS v6.55

As for all nutrients, AA requirements depend not only on maintenance needs and the immediate needs for milk performance, but also on the AA needs for the well-being of the dairy animal such that she can fend off disease, reproduce regularly and have a long, productive life.

Pre-fresh

This is the most important stage of lactation for the nutrition of the dairy cow. The preparation for calving is paramount for predisposing a successful lactation.

Enriching the close-up diet with MET and ensuring adequate LYS is essential. Current recommendations are to add a minimum of 5 grams of MET to the basal level, which typically results in a total supply of 35 grams of MET. Target a LYS to MET ratio of 2.60 to 1 in order to maximize antioxidant and immunity status at calving.

Post-fresh

To consolidate further the postpartum benefits of pre-partum AA ration balancing and to support the development of DMI and lactation performance, continue with the same target LYS to MET ratio of 2.60 to 1 for the first four weeks of lactation or at least for the period she stays in the fresh pen.

Equally important is to ensure ME supply. During this period, mobilized energy reserves will be a significant contribution, therefore, it is important to target as high a concentration of LYS and MET (g per MCal of ME) in the ration > 1.10 g / MCal for MET.

Full Lactation

Once the cow is in full lactation, she is dependent on the diet to supply all her nutrient needs. Therefore, all nutrients need to be supplied in concert within the DMI constraints of the diet (forage quality and NDF characteristics). Energy intake drives performance, and LYS and MET are necessary to optimize this potential. When diets are amino acid balanced, there is no longer an interest to formulate for MP as a primary constraint. Optimum formulation levels for CNCPS v 6.55 are 1.19 g MET per MCal at a LYS to MET ratio of 2.69 to 1.

The table below shows typical nutrient targets for cows in full lactation, not gaining or losing weight, producing 45 kgs of milk 4.0% fat and 3.2% true protein, eating 26.5 kgs of DM. A ration formulation that meets these targets is provided for reference. This is for indicative purposes only. Solution formulations will vary widely in ingredient composition depending on forage inventory, quality and the price of complementary feeds. Quality protected-lysine sources are often a valuable and cost-effective ingredient to reach target Lys levels in the ration, particularly where selected high-quality bloodmeal is not available or is not an option in most parts of the world.

Reference ration formulation for cows in full lactation

Feed	DM kgs	Nutrient	Supply
Corn Silage	9.2	ME (Mcals)	70.3
Alfalfa Silage	3.7	ME Allowable ECM kgs	47.9
Straw	0.5	Forage aNDF (%DM)	20.9
Whole Cottonseed	1.2	NFC (%DM)	44.0
Soybean hulls	0.5	Fermentable Starch (%DM)	20.0
Molasses	2.1	Sugar (%DM)	8.5
Ground Corn	5.0	EE (%DM)	4.7
Soybean Meal	1.4	CP (%DM)	15.4
Treated Soybean Meal	2.0	MP (g)	3,100
Palm Fat	0.14	NH3 (%Req.)	118
Minerals & Premix	0.7	MET total (g)	77.4
Smartamine M	0.019	MET added (g)	11.8
		MET (g per Mcal of ME)	1.10
		LYS (g per Mcal of ME)	2.96
Total	26.5	LYS:MET	2.69:1

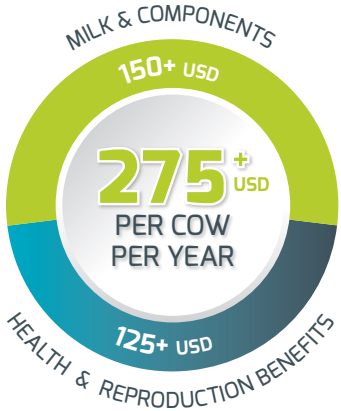
AMINO ACID BALANCING

The Profitable Sustainable Solution to Meeting Dairy Cow Requirements for Lifetime Performance

Amino acid balancing is a critical cog in balancing dairy rations for lifetime performance. Profitability accumulates from the savings in less metabolic disorders post calving, improved performance immediately post calving due to enhanced feed intake, a more rapid rise to peak lactation and subsequent sustained performance throughout lactation which maximizes milk component yields. AA balancing plays a key role in supporting better reproductive performance and facilitating less involuntary culling.

Amino acid balancing can improve net income per cow per year

- **Higher milk performance**
- **Health benefits (saving money): fewer health disorders**
- **Reproductive benefits: lower pregnancy losses, reduced calving interval**
- **Lower involuntary culling**
- **Reduced days in milk**
- **Greater lifetime performance**



Average global prices May 2023

Improvements in profitability will vary from farm to farm. Some macro economic factors such as milk pricing, particularly milk component pricing, will have a marked influence. For example, the U.S. and certain countries in Europe stand to gain more in net income from milk and milk components as pricing mechanisms reward improving milk protein and fat yield. Nevertheless, as an order of magnitude, the benefits to AA balancing can be divided as follows 50% plus through enhanced performance and nearly 50% derived from improved health and reproduction. For a daily investment of 20 to 30 U.S. cents/cow (60 to 90 U.S. dollars per lactation) in AA balancing, the anticipated improvement in farm income is 200 to 300 U.S. dollars per lactation.

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SUSTAINABILITY
each company's and individual's responsibility

THE ADISSEO CONTRIBUTION
continues to expand

RUMINANT CONTRIBUTION
to climate change (GHG) – measurable and decreasing

IMPROVE NITROGEN EFFICIENCY
reduce CP and AA balance

LOWER CARBON FOOTPRINTS
choose feedstuffs with low carbon footprints

INCREASE HERD LONGEVITY
meet requirements for methionine, an essential nutrient

Smartamine®
MetaSmart®

Adisseo is committed to helping the feed industry find scientific and technical solutions to current field challenges.

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