Fermentation– the essential element of ruminant nutrition

WHEN JOHN BAX LOOKS AT A COW, HE SEES A CONTAINER FOR MICRO-ORGANISMS. LIMIN KUNG HAS 30 YEARS' EXPERIENCE IN USING MICROBES TO IMPROVE SILAGE QUALITY, WHILST CHARLIE SNIFFEN BELIEVES PUTTING ALL THIS INFORMATION INTO AN EFFECTIVE MODEL WILL HELP US IMPROVE RUMINANT NUTRITION. THESE EXPERTS MET RECENTLY IN MONTREAL TO DISCUSS HOW BUGS WILL SHAPE THE FUTURE. BY SARAH MELLOR.

Ruminants couldn't survive without a functional rumen ecosystem. In optimal ruminant production, micro-organisms play a much more integral part. They are involved at every step, from forage preservation to productivity models. Dairy management would be unthinkable without microbial activity, but acknowledging their presence is simply not enough. There is plenty of scope to manipulate microbial communities and plenty of research being conducted to refine such practice. It is for this reason that Lallemand Animal Nutrition's North American division brought international experts to a seminar in Montréal, Canada in June, to divulge research experience and practical advice.

MAIZE SILAGE - AMERICA'S SWEETHEART

Professor Limin Kung of the University of Delaware is perhaps the world's best-known silage expert. With 30 years' experience in silage fermentation, there is little he doesn't know about getting the best from forage. In the US, he explained, maize is by far the most popular forage crop for silage. "There is a mindset that it is very hard to make bad corn silage", he said.

Maize ensiles well, resisting clostridial fermentation, fits well into a total mixed ration and mixes easily. "Forty to fifty percent of the crop is grain, so maize silage is really a forage-concentrate hybrid."

The few problems that can arise are with acidosis and its poor aerobic stability. Maize silage also has only a moderate effective fibre content and can be acidic. Another concern is the high variability in nutritive value. Selection processes are addressing this issue, resulting in varieties like the brown midrib (BMR) maize, whose lower lignin content improves its digestibility, consequently increasing intake and milk yield when it is included in dairy rations.

A special case, Kung illustrated, is that of the high moisture maize that has become popular in the upper mid west of the US, where it is used on 50-60% of the beef feedlots. Around 70% of the 16,000 dairy farms of Wisconsin feed high moisture maize. Only the grain is ensiled (the husk and cob are removed), whose moisture content is 27-30% (hence the name). Its popularity grew because it is inexpensive, can be grown on-farm and is highly palatable. Disadvantages include its narrow harvest window and its poor shelf-life due to the high starch content.

ENSILING'S TRADE SECRETS

Despite maize silage's good reputation, 10-20% nutrient losses due to poor fermentation, silo management and aerobic instability can lead to heavy financial losses. These, said Kung, can "make silage quite expensive, even if it's home grown." Only around 5% of losses are due to fermentation, explained Kung; the rest are essentially storage losses. Exposure to air encourages yeast to grow by metabolising lactate; this produces heat and raises the pH, which precipitates spoilage on a massive scale.

The trick is to establish a rapid fermentation initially, decreasing pH, thus inhibiting pathogen growth. This also has the advantages of improving dry matter and energy recovery and sometimes helps increase milk production. Improving aerobic stability reduces yeast and mould growth at the silo face, preventing overheating and spoilage.

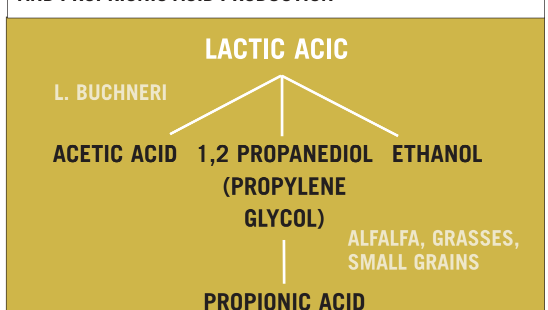
A number of different approaches are used, but in Kung's experience, silage inoculants prove the most reliable approach. For the past five years he has been improving aerobic stability using *Lactobacillus buchneri* 40788. This inoculant, he says, "goes against all the dogma that says 'only homolactic fermentation is good.' *L. buchneri* 40788 is heterolactic, but improves fermentation. Lactic acid by itself, or low pH, for that matter, *doesn't* inhibit yeast growth." *L. buchneri* 40788's metabolism of lactic acid in maize silage produces mainly acetic acid (*Figure 1*), an effective anti-fungal agent. In alfalfa, grasses and small grains, propionic acid will also be produced. A number of published studies, including Kung's own work, have demonstrated its improvement of the aerobic stability of different silages (maize, barley, wheat and sorghum, high moisture maize, ryegrass and alfalfa), which could give an acetic acid concentration of around 5% in maize silage, sufficient to reduce yeast concentrations to 10 CFU/g or less. This same high dose also dramatically increased aerobic stability from 68 hours to more than 572 hours.

Kung's experience has shown that such a high dose is necessary to increase the acetic acid production that stabilises the silage. Other studies have shown *L. buchneri* 40788 to be equally effective when used as an inoculant in high moisture maize silage.

Finally, Kung turned his attention to application methods. As with all inoculants and additives, the product can only be effective if it is well distributed. Lactobacilli are non-motile, so distribution is important and being live organisms, water activity is vital to their efficacy, so in high dry matter silages, liquid application is a must. As a final

"If you really want good use of inoculants, you have to talk to the people doing the application" Limin Kung knows good silage- and how to get it.

FIGURE 1 - L. BUCHNERI METABOLISM RESULTS IN ACETIC AND PROPRIONIC ACID PRODUCTION



word, Kung recommended, “If you really want good use of inoculants, you have to talk to the people doing the application. Stop them adding the products blind, because calibration and water are so important.”

”It is tempting to feed the cow as a monogastric animal”, but Lallemand’s John Bax wouldn’t recommend it.

OPTIMISE RUMEN EFFICIENCY…

John Bax, technical support manager for Lallemand in the UK, has a particular interest in optimising rumen function. His opening statement was clear, “We can no longer get away with feeding cows badly”. Whilst “Good management of these processes is vital for the performance and well-being of the host animal,” microbial activity is not visible to the human eye. “Remember, we are feeding the rumen bugs, not the host animal. It is tempting to feed the cow as a monogastric animal”, but Bax wouldn’t recommend it. Improvements in genetic potential and nutrition (which unfortunately often lags behind) mean that the average milk yield of dairy cows has increased by 20% in the last 12 years, “but the rumen microflora are still the same”, he said, “so we need to get more out of feed.”
The cow’s bite rate is no more than 50-60 times a minute for a maximum of 11 hours, so a diet should be edible, but the cow should be able to extract more nutrients from it. This is where the rumen microflora come in. Rumen fluid contains 150 billion microbes (bacteria, protozoa and fungi) in every 5 ml (Bax compared this to a world human population of only 5.9 billion people). Fermentation occurs at a massive level, so it is vital to get its basis right by giving the correct diet.

…OR ELSE!

The dynamic balance between fibrolytic and starch digesting (amylolytic) bacteria, fungi and protozoa pivots on the relative content of fibre and starch in the diet, which impacts rumen pH. As rumen pH falls, microbial activity changes from cellulolytic to amylolytic until pH 5.5, when lactobacilli predominate and *S. bovis* and acute acidosis are obvious. A bigger problem, said Bax, is sub-acute ruminal acidosis (SARA), which occurs within the amylolytic pH range of 6.0-5.5 within which many cows, he explained, are typically managed. Signs of SARA include reduced rumination, increased variation in individual intake, changes in faecal texture (including “bubbly” manure) and undigested feed appears in the faeces. At rumen level, fermentation of carbohydrates, NDF and soluble fibre has decreased; the rumen pH drops to below 6.0, where enzyme function is compromised and the growth of fibrolytic bacteria slows. Back at stall level, milk production is reduced, its composition disrupted, digestive upsets are more evident and the incidence of laminitis increases. Even after acidosis is corrected, the damaged rumen tissue does not have the same absorptive capability as before.

SARA and laminitis are most often seen in high intake, sorting animals (a good reason to ensure the TMR is well mixed, added Bax), that have recently calved, but this group is not exclusive. “The stresses on the rumen imposed by current production systems can start from the moment a calf is born”, he warned, “and cause or contribute to a wide range of problems”. Early separation and early weaning mean that calves’ opportunities for microbial transfer from the dam are limited: “the rumen is stressed even before it’s a rumen”. The problems can manifest all through the cow’s productive life: as decreased immune status; increased incidence of digestive upsets; reduced fertility; metabolic stress at calving; as well as productivity losses and lameness.

SARA causes laminitis

Laminitis is a multifactorial syndrome, associated with lower rumen pH and histamine concentration. A drop in rumen pH leads to a reduction in systemic pH, which increases total blood flow. Blood pressure is further increased by endotoxin and histamine production. Histamine is an arterial dilator and vasal constrictor - thus blood accumulates in the capillary beds where is causes vessels to rupture, serum seepage and haemorrhaging. Acidosis also promotes *Fusiformis necrophorus*, which permeates the rumen wall. Once in the portal circulation it causes liver abscesses as well as the release of more histamine. More recent findings show that *Allisonella histaminoformans*, an acidophilic bacterium that uses histidine as an energy source, produces histamine, thus aggravating an already destructive situation.

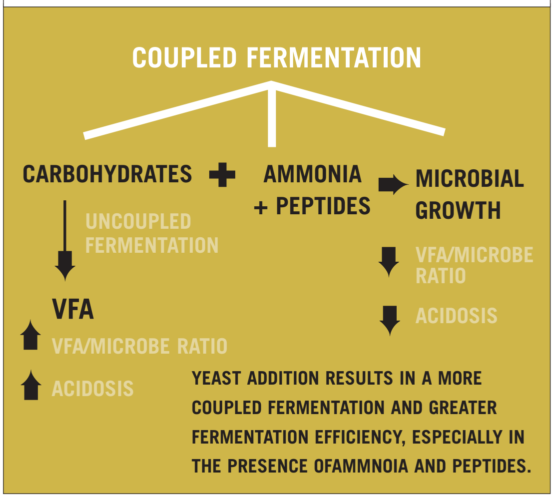
STABILISE RUMEN FERMENTATION

The rumen is a complex functional system that is extremely difficult to replicate *in vitro*. Its physiology, microbiology and biochemistry evolved to utilise forage diets. When the system is unbalanced by any one of the stresses placed on it by modern management and productivity demands, some degree of acidosis is almost inevitable. The biochemical mechanisms behind acidosis have been reported extensively elsewhere (e.g. *Feed Mix* Volume 11 Number 4, pp. 30-34), as have the way in which *S. cerevisiae* CNCM I-1077 (fed as Levucell SC I-1077, Lallemand Animal Nutrition) has been used successfully to reduce the extreme drops in pH effected by lactate production from high starch diets (sheep; Michalet-Doreau and Morand, 1997); increase rumen fibrolytic activity (Chaucheyras-Durand and Fonty, 2001) and increase fibre digestion in lambs (Chaucheyras-Durand and Fonty, 2001) and steers (Schwarz *et al*., 2002). In practice, live yeast can be added to TMR’s (added to the mineral mix), mash or pelleted feeds. The trick, explained Bax, is to get accurate dispersion within the diet. Encapsulation has improved the heat and pressure resistance of the additive, allowing it to survive pelleting.

“THE OPPORTUNITIES ARE GREAT”

So says Dr. Charles Sniffen, of Global Dairy Consultancy Ltd. in the US (for more information, visit www.globaldairy.net). A retired professor of nutrition at Cornell University, Sniffen has been using nutritional models to quantify the impact of live yeast addition on rumen kinetics and ultimately on productivity, essentially optimising the ration formulation. Model development, explained Sniffen, is a means of organising our knowledge of a system so that we can accurately predict the outcome of any changes we make at the level of input. The models that we develop need to represent the biology at least one level lower than what we are trying to predict, he explained. There are a number of models currently in use for dairy

FIGURE 2 - RUMEN FERMENTATION COUPLING



cow ration formulation. Sniffen described four such models: one of the most recent is the Dairy Forage System Model (DAFOSYM) which simulates the performance, environmental impact and economics of a whole dairy farm over multiple years of weather, from forage production to manure handling; Cornell University's Net Carbohydrate and Protein System (CNCPS) models the herd or production groups within it, including calves, dry cows and milking cows; the CPM Dairy software is one of the most widely used dairy ration formulation programs, whilst the NRC 2001 requirements are also still in widespread use: both these model the individual cow. These models show a downward trend, said Sniffen, from farm level towards the cellular and genetic levels.

MODELS IN ACTION

If this all sounds a bit daunting (the idea of genetic analysis to develop a ration formulation does sound a bit extreme), Sniffen is reassuring, "We're not going to be doing this", he says, "we will, but we won't know we are. The models will be incorporated into the nutritional formulation." Some of the more recent models are being used in the field already and are helping to improve performance. Model development for ration formulation is based on refining the measurements and fitting them into better models so that the variance is captured and explained. Improvements in gastrointestinal modelling, especially at rumen level are especially useful in predicting responses to nutrients and feed additives.

One example of this is a project initiated in the summer of 2003 to define nutritional guidelines for optimising the use of an active dry yeast additive (Lecucell SC I-1077) for milk production. The idea was to develop a quantitative model to link the INRA mode of action studies (as described by John Bax, above) with the performance data (193 observations from 14 lactating cow studies), so that new studies could be designed to fill in the gaps and explain the variation in responses to yeast. The diets used were analysed using CPM 3.0, to establish which dietary factors had the most impact on the cow's response (in terms of milk yield, milk composition and dry matter intake). Briefly, regression analysis showed that increasing the diet's rumen degradable protein (RDP) content increased the cow's response to yeast, with a maximum response at 11.5% RDP (this is 10-15% higher than the NRC's recommendation). Qualitatively, explained Sniffen, this supports the concept of rumen fermentation coupling (*Figure 2*), as described by Jim Russell's work at Cornell University (Thomas and Russell, 2004). Without sufficient ammonia and peptide supply, carbohydrate fermentation in the rumen will result in more VFA production and impaired microbial growth, reducing rumen pH and increasing the risk of acidosis. Coupling nitrogen and carbohydrate supply, as enhanced by the presence of ruminally active live yeast, allows increased biomass production and prevents the problem. Furthermore, analysis of the data revealed that improving rumen fermentation in this way also results in more efficient use of rumen ammonia and less nitrogen wastage; and preventing a drop in rumen pH improves fibre digestibility - also valuable in reducing nitrogen waste. When incorporating active dry yeast into the diet formulation, Sniffen's calculations recommend increasing the content of sugars, soluble fibre and fermentable NDF to improve the cow's response to yeast addition. Reduced levels of physically effective (pe)NDF can be tolerated, while yeast affords the opportunity of increasing levels of fermentable carbohydrates to increase microbial protein production without the threat of acidosis. Sniffen's belief in the power of modelling is clear. Concluding, he emphasised the need for integrating basic and applied research with improved modelling techniques to help design rations that will improve rumen efficiency and hence production. Of course, there is still a long way to go and a lot of data to be generated, but "The opportunities are great". <-

Prediction of milk output ultimately requires a good rumen model, says Professor Charles Sniffen

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