Nutrition and immunity in the newborn calf: new advances from yeast based technologies

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SUMMARY
Mortality rates in the newborn calf have not changed in the last ten years in the national dairy herd, despite improvements in management and feeding techniques. The reported mortality is primarily because of enteric diseases within the first few weeks of life and a failure of transfer of passive immunity from dam to calf. The nutrition of the cow and calf in the periparturient period can play a vital role in the early development of immunity in the neonate. In recent years, new technologies have emerged that are reported to have a beneficial impact in preventing and aiding recovery from disease episodes. This short review considers some yeast based technologies that have demonstrated creditable results when incorporated in to either the maternal or neonatal diet. In particular, yeast cell wall derived mannanoligosaccharide and its role in intestinal health and development is discussed, along with yeast nucleotides and their impact on intestinal morphology. Mineral nutrition of the periparturient cow is examined with emphasis on the two trace elements, selenium and iodine.

Keywords: Nutrition, immunity, mannanoligosaccharide, nucleotide, selenium, iodine, dairy cow, calf.

Introduction
The health of the newborn calf is a limiting factor in achieving genetic growth potential. Globally, the size of individual dairy herds is increasing, which brings about many new challenges for the farmers, such as overcrowding issues. With increased cow numbers, there will also be increased heifer calves for rearing. Whilst much thought is put in to new housing for the lactating animals, often very little is reserved for the calf housing. The potential increase in stocking density of the calves will bring it’s own stresses and increased risk of disease and mortality. The majority of calf mortality occurs within 3 weeks of life and usually due to enteric problems, such as salmonella, E. coli, clostridia inter alia. BLOWEY [2] estimated calf mortality in the United Kingdom of live-born calves to be 2-5%. More recently, BRICKELL [5] surveyed farms in southern England and found neonatal mortality to be 3.4%, agreeing closely with BLOWEY [2]. In both cases, this mortality is described as calves born alive and dying within the first month of life.

Where perinatal mortality is considered (described as any calf born dead or dying within 24 hours), BRICKELL [5] found this to be 8.1%, ranging from 3-14%. ESSLEMONT and KOSSAIBATI [7] put this figure at 7.8%, so there has been a negative progression in 11 years. Further, in 1992, it was estimated in the USA that 50% of pre-weaned calf mortality was directly related to inadequate passive immunity [18]. Costs associated with mortality before weaning could be as much as €260 per animal [8].

Maternal Nutrition
Immunity against pathogen loading and viruses begins with the dam. Calves are born with an immune system that is naive and must be “taught” before it is able to respond fully to pathogenic challenges on its own. The second and third week of life have been found to be the most critical in terms of calf mortality and could be viewed as a “weak” period where the effectiveness of passive immunity is lessening.

RÉSUMÉ
Nutrition et immunité du veau nouveau-né : nouvelles données
Le taux de mortalité des veaux nouveaux-nés n’a fondamentalement pas changé au cours des dix dernières années, malgré les progrès notables en terme de gestion d’élevage et de nutrition. La mortalité rapportée est principalement due à des pathologies intestinales apparaissant dans les premières semaines de vie ainsi qu’à un taux d’échec élevé de transfert de l’immunité passive des vaches à leurs veaux. L’alimentation de la vache et du veau dans la période entourant le vêlage peut jouer un rôle primordial dans le développement de l’immunité du veau nouveau-né. Au cours des dernières années, de nouvelles technologies ont été testées avec un effet positif sur la prévention et rapidité de guérison lors d’épisodes pathologiques. Cette revue courte considère l’emploi de produits à base de levures qui ont montré des résultats positifs lorsqu’ils ont été introduits dans l’alimentation de la vache gestante ou dans celle de son veau dans les jours suivant sa naissance. L’emploi de mannan-oligosaccharides extrait de la paroi de levures ainsi que de nucléotides issus de levures sera en particulier évoqué quant à leurs effets bénéfiques sur l’équilibre de la flore intestinale et le développement de la muqueuse intestinale. L’alimentation en oligo-éléments de la vache gestante est abordée, avec une attention particulière portée au rôle du sélénium et de l’iode.

Mots clés : Nutrition, immunité, mannanoligosaccharides, nucléotide, sélénium, iodine, vache, veau.
and adaptive immunity is not fully functional [25]. Colostrum is the calves main defence mechanism until the active immunity is fully developed over the first month. Clearly, enhancing colostrum quality and the potential for uptake of the immunoglobulins is vital.

**Mannanoligosaccharides**

Recently, there has been much interest in the use of glycomics in animal nutrition. The functional role of certain carbohydrates in biochemical processes is being defined. The Type 1 fimbral agglutination of mannose by bacteria has been known since the 1960’s. Mannanoligosaccharides (MOS) from the outer cell wall of *Saccharomyces cerevisiae* are attracting interest with their antigenic behaviour. It has been established that the β-glucans cross link the proteins and that this makes these proteins effective [15]. The MOS are comprised with over 50% carbohydrates forming fimbriae [17]. Studies on a particular mannanoligosaccharide – Bio-Mos® (Alltech Inc, KY, USA) - have shown that strains of *Salmonella* and *Escherichia coli* will agglutinate to it in vitro and that it will thus act as a competitive, non-absorbable binding site in the intestinal lumen [23]. Bio-Mos® was first studied in milk replacer for calves in 1993 [20], where improvements in weight gain and a reduction in respiratory infection was seen. Since then, numerous studies have evaluated the efficacy of this MOS in all species.

Researchers at the University of Kentucky found that supplementing the diet of precalving cows with 10g of the mannanoligosaccharide Bio-Mos® improved the response to a vaccination program against rotavirus. The cows were vaccinated at 4 and 2 weeks before expected calving date and blood measurements taken at calving and at 24 hours in cows and their calves. Specific immunity was improved in the cows and there was a tendency for the calves to have enhanced serum rotavirus neutralisation titres at 24 hours after birth. The calves from cows supplemented with the MOS also tended to have higher serum protein concentrations [9]. These results demonstrated that the use of this MOS in the precalving diet of cows could enhance the response to specific immune responses and also improve the passive transfer to calves via the colostrum.

**Selenium**

The mineral requirements of dairy cows was reviewed in 2001 by the National Research Council [19] in the USA. However, the effect of differing sources of trace minerals, in particular chelates and organic sources was not fully explored. Selenium is well known as a major component of the immune system and likened to being the keystone nutrient therein. The best known selenoprotein is glutathione peroxidase (GSH-px) and this is also involved in intestinal protection of membranes.

Silvestre [22] examined the effect of replacing sodium selenite with organic selenium yeast (Sel-Plex® Alltech Inc, KY, USA) in Florida dairy cows. The study started 3 weeks pre-calving with cows fed 0.3 mg/kg DM selenium as either form. The cows fed Sel-Plex® had significantly higher plasma Se concentrations (87µg/ml versus 69µg/ml), showed a significant decrease in fever in multiparous cows by day 10 post calving (13.2% versus 25.4%) and improved uterine health. The cows fed Sel-Plex® also had greater second service pregnancy rates and produced more milk. In Canada [14], researchers evaluated the effect of Se source on neutrophil function and apoptosis. Cows receiving organic selenium (Sel-Plex®) in place of sodium selenite had neutrophils that could produce a greater oxidative burst. Interestingly, apoptosis of the neutrophils was not different between Control cows (receiving no selenium supplementation) and cows receiving Sel-Plex® (6% and 5% apoptosis, respectively). However, cows fed sodium selenite had 20% apoptosis of the neutrophils.

GUYOT et al. [11] at Liège University, Belgium, tested the effect of replacing sodium selenite with organic selenium yeast (Sel-Plex®) in the diets of Belgian Blue cows and examined the impact on calf health. The cows fed Sel-Plex® produced colostrum and milk with higher selenium content. Only calves from these cows were born in good selenium status (>70µg/l plasma) and they had lower incidence of neonatal diarrhoea. The average daily gain of the calves from Sel-Plex® fed cows also tended (P=0.06) to be greater, though there was a bias in the sex ratio of the calves that may have caused this trend.

**Iodine**

Selenium also plays a role in the utilisation of iodine, through the conversion of tyroxine to triiodothyronine via the selenoprotein iodothyronine 5'-deiodinase. Awadeh [1] tested the effect of level and chemical form of selenium on thyroid hormones. Calves from cows supplemented with 60ppm Sel-Plex in the mineral salt had higher T3 at birth than calves from cows supplemented with either 20 or 60ppm selenium as sodium selenite. As T3 is required in growth and metabolism, this may go some way to explaining the greater rate of gain in the Belgian study above.

The EU maximum inclusion of iodine is now 5.7mg/kg of dry matter intake in ruminant animals having been reduced by 50% in 2005 after concerns of transfer of high levels in to milk and meat for human consumption. This caused concern in many European countries where iodine deficiency in dairy cattle was considered widespread, despite a lack of evidence. Interestingly, a series of studies carried out in Ireland at the University College of Dublin, reported that feeding mineral supplements to ewes resulted in a very significant depression in the uptake of IgG by the newborn lamb [3, 6, 10]. This was true if the supplementation occurred in the final 2 weeks prepartum and did not vary on source (powdered mineral, liquid or block). BOLAND et al. [4] in a series of three further experiments examined individual minerals and found that there was a negative linear reduction in serum IgG concentration and absorption efficiency in lambs as the maternal iodine supplementation increased. Neonatal health is dependent upon IgG transfer from the dam and it has been
demonstrated that overfeeding iodine has a detrimental impact on IgG uptake in lambs. It is not known if the same would be true in cows and calves, however, ensuring an adequate selenium status of both the cow and calf may have a role in allowing lower levels of iodine to be included in the daily diet, thus potentially avoiding the negative effects seen in sheep.

Calf Nutrition

MANNANOLIGOSACCHARIDES

As previously discussed, the uptake of IgG by the newborn animal is greatly influenced by maternal nutrition. The use of mannanoligosaccharide from *Saccharomyces cerevisiae* (Bio-Mos®) in the diet of calves has also been examined. A study at Penn State University compared Bio-Mos® (4g/day) to antibiotics (Neomycin® and oxytetracycline) and a negative control in milk replacer for calves up to 6 weeks of age [12]. They concluded that the Bio-Mos® was equally as effective as the antibiotics, leading them to conclude that the MOS could replace the antibiotics in milk replacer formulation. By blocking the attachment and colonisation of the intestine by gram negative pathogenic bacteria with Bio-Mos®, the autogenous population is in a less stressful environment making the gut more efficient, and there will be more nutrients available for lean tissue growth and immunity.

TERRE et al. [24] also examined the effect of Bio-Mos® in milk replacer on calf health in an enhanced-growth feeding program. Inclusion of the MOS stimulated greater starter feed intake post weaning and resulted in a significant reduction in Cryptosporidium spp in the first week of supplementation. Further research in Australia [21] demonstrated positive effects on intestinal morphology with the inclusion of mannanoprotein (Bio-Mos®) in the milk replacer from day 2 to 21. Serum IgG loss was reduced with supplementation and villi height increased in the ileum. The defence functions of the Peyer’s patches were also enhanced through greater numbers of T cells.

Bio-Mos® also facilitates changes in the mucin production in the intestinal lining. This could be due to the upregulation of gene expression in crypt cells and brush border transporter proteins [26]. Greater mucin production allows for better protection against pathogen attachment and enhanced nutrient uptake.

These benefits of MOS in the diet of pre-weaned calves are not restricted to health. Hooge [13] carried out a meta-analysis of 17 studies involving Bio-Mos® being incorporated into milk replacer. The average improvement in weight gain was some 15%, equating to a daily weight gain increase of 70g per day.

NUCLEOTIDES

More recently, a source of nucleotides also from *Saccharomyces cerevisiae* (Nupro®) has been used in early calf diets via milk replacer. Compared to negative control and a diet containing purified nucleotides, the Nupro® fed calves had improved intestinal morphology (through increased abundance of nucleoside transporter mRNA and lower alkaline phosphatase), increased beneficial intestinal microflora and a decreased diarrhoea incidence [16]. The yeast derived nucleotides caused a numerical increase in villi length and slightly greater xylose uptake.

Conclusion

New technologies are being developed that may allow for improved calf health without the use of antibiotics. Studies are showing benefits to newborn animals through a decrease in the incidence of enteric disease, improved IgG uptake and lower mortality. These benefits can be transferred to the neonate via colostrum from supplementation of these technologies to the dam.

Conflict Statement

The author previously worked for Alltech (UK) Ltd.

References


The relationship between trace elements status and health in calves

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SUMMARY

This paper reviews the present knowledge on the relationship between selected trace element nutrition of cows or calves and the health in calves. Trace elements deficiencies can lead to specific diseases relating to specific nutritional functions; myopathy for selenium, goitre or thyroid dysfunction for iodine, anaemia for iron. Insufficient status of copper, zinc and mainly selenium can lead to a decrease of defences, mediated in the newborn calves by a low transfer of immunoglobulin from thecolostrum, and in older calves by a depressed acquisition of immunity. These effects on immunity have more often been demonstrated experimentally on biological markers of immune defences than on the incidence of diseases. However, large scale survey can evidence an increased risk of diseases, mainly diarrhoea, in calves from herds with poor trace element status. As a consequence, deficiencies must be avoided, particularly in late pregnancy cows, by meeting recommended allowances without imbalances, and checking the nutritional status of animals when the dietary supply is uncertain.

Keywords: Calves, trace elements, copper, zinc, selenium, iodine, iron.

RÉSUMÉ

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Introduction

The objective of this paper is to review information concerning the influence of trace elements nutrition of cows and calves on the health of calves. In calves, the effects of trace element deficiencies can be observed in newborn animals, whose trace-elements stores are in relation with maternal nutrition. Indeed, the trace elements status of newborn calves depends on maternal transfer via the placenta, the colostrum or the milk. For this reason, maternal nutrition can be considered as a major determinant of the status of young calves, affecting directly their health. Deficiencies can also be observed in older calves but they are then due to an insufficient supply in their diet.

The effects of trace elements deficiencies in animals have been described for a long time. First described effects were clinical signs, some of them being specific enough to provide a diagnostic relative to one trace-element deficiency. Such specific effects are usually observed only with strong deficiencies. Moderate deficiencies mainly result in non-specific disorders, decreasing growth or affecting health, mainly via depressed immune defences.

Evidencing the effects of trace element deficiencies on animals can be made via experiments, mainly based on the effects of trace element supplementation, or via large scale surveys in commercial herds. In a recent retrospective study [13], based on a data set of analysis in 2080 dairy and beef cattle herds in France and Belgium, copper, zinc and selenium status of herds were investigated as risk factors for health problems in calves. Available data were:

- health problems in dams and calves in the herd,

- individual trace-element status of adult cows assessed by plasma copper, plasma zinc and erythrocyte glutathione peroxidase activity. Herd statuses were classified as deficient, marginal, low-adequate or high-adequate, based on the lower tercile of individual values. Table I shows the main relationships observed in this survey between trace-element status of adult cows and major health disorders of calves, calculated as odd-ratios comparing case herds and control (without health abnormalities) herds. This table shows that all three trace elements can be involved as risk factors for health problems in calves.