Challenge management for dairy cows

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Introduction Dairy farms are managed with the objective to obtain a profitable enterprise delivering market-driven products. Therefore, farmers must supply the market with high-quality products from healthy animals at a reasonable price and produced within an environmental and public framework. This will not only challenge dairy farmers, but dairy cows as well. Feeding strategy and diet composition are crucial factors within dairy farm management. On the environmental aspect, feed is one link within the nitrogen and phosphorus cycle and is an important factor affecting greenhouse gas emissions and manure quality. Animal nutrition also influences milk composition. Optimum feeding is the key to prevent metabolic disorders around calving, which has a direct effect on the immune system and reproduction of dairy cows. Feed is also an imported debit for the dairy farm, besides labour and land costs. Dairy cows, farmers, feed industry and researchers are challenged to find the optimum feeding strategy to meet these various conditions.

Protein nutrition Although protein utilisation of dairy cows has been studied for 170 years, the relationship between protein nutrition and emissions to the environment has become an issue only during the last 30 years. The main objective has been to improve N utilisation within the animal. However, nowadays the dairy cow is regarded as an important link within the nutrient cycle: “feed - cow – manure – soil - feed”. Decreased losses from this cycle can be obtained by lowering N inputs through fertiliser and feed supplements. Such measures can also affect feed quality and protein supply to the dairy cow. The challenge therefore is to obtain an optimum nutrient supply which results in a profitable enterprise and a healthy cow herd at low levels of N input. Further studies are planned to improve protein management at rumen level, to use absorbed amino acids more efficiently and to recycle unused N (urea). Lower protein levels can have a positive effect on reproduction. High concentrations of urea in blood are suboptimal for embryonic survival. Summarising various studies, Yawongsan (2007) concluded that the conception rate in cows with a milk urea concentration below 40 mg/100 ml was higher than above 40 mg/100 ml. From an environmental point of view the on-farm N input through leguminoses, such as clover, should not be ignored. It should be realised that this N-input “by air” is also not completely utilised and therefore contributes to the emissions of ammonia, nitrate and nitrous oxide. This N input should therefore be taken into account in the farmer’s N management.

New feed ingredients, obtained as by-products of biofuel industry, in general are rich in N. A higher supply of these ingredients may reduce the use of other protein sources, but should not lead to an increase in N losses.
The dairy sector should be aware of the nutrient cycles in a broader view. Within smaller regions, cooperation between farmers may lead to exchange of manure against feed ingredients. On a global level the “ecological footprint” of imported protein sources will play a role as well. In ongoing studies in both feed industry and research this topic is emphasised.

**Green house gasses** Ruminants have a high priority in reducing the emissions of greenhouse gasses. Methane is produced in the rumen as a result of anaerobic fermentation of biomass. Reducing methane production by feeding strategies, feed composition and feed additives has been attempted for many decades, because methane is loss of valuable digestible energy. Results were not very promising and one of the few effective measures is regarded as a growth promoting antimicrobial agent, and thus no longer admitted within the EU. Recent attempts to reduce methane emissions seem quite effective, with reductions of 30%, but these were mainly in vitro studies. Earlier studies have shown that the rumen microbial population can adapt their “hydrogen” metabolism to many feed additives. Feeding strategies to reduce methane emission seem contradictory to other nutritional management. Methane production decreases on diets with a relative low proportion of forage or a relative high proportion of rumen-degradable starch. A low proportion of forage conflicts with strategies to increase the proportion of home-grown feed, to pasture dairy cows for considerable periods and to prevent rumen fermentation disorders such as (sub)acute rumen acidosis, resulting in lower performance and other metabolic disorders. A high proportion of starch-rich ingredients in the diets, not only enhances the effect of low forage diets, but is also conflicting with the global strategy to use valuable nutrients sources (starch and protein) for human consumption. Therefore, direct management strategies could be only a limited contribution to methane emissions. Production of greenhouse gasses can also be expressed per kg of edible product. On such a basis other management strategies may be useful as well. A higher production level and a higher longevity of the animal will increase the efficiency of nutrient use per animal. Using the individual variation between animals in nutrient efficiency is another management tool to minimise nutrient losses. Dynamic Feeding uses the individual variation and aims to use nutrients at those stages where the effect of nutrient supplementation in an individual animal is maximal.

**Milk quality** Milk composition is relatively constant and nutrition management to manipulate milk composition is effective only for concentrations of milk fat, milk fatty acid composition, fat-soluble vitamins and some micro-minerals such as Se, J and Cr. During the last decade, the relationship between fatty acids and human health has become an important research topic. Various studies demonstrated that the incidence and severity of coronary heart diseases (CHD) and cancer was negatively related to the intake of poly-unsaturated fatty acids (PUFA), especially the omega 3 long-chain fatty acids and conjugated linoleic acids, respectively. Because milk fat contributes to the fatty acid consumption in humans, studies have been carried out to manage milk fatty acid composition by feeding strategies. In ruminants, PUFA are almost complete hydrogenated in the rumen, whereas certain intermediates of this bio-hydrogenation may result in a milk fat depression. Thus, to increase the concentration of omega 3
PUFA in milk these fatty acids have to be protected against the influence of rumen micro-organisms. Until now, most studies aimed at increasing the proportion of linolenic acid (omega 3 C18:3). However, only a few studies aimed at increasing DHA and EPA in milk. These marine PUFA have a higher biological effect on CHD than the C18 fatty acid.

Dairy cows are unique in the production of conjugated linoleic acid (C18:2), especially rumenic acid. Specific feeding strategies are required to increase this PUFA in milk, including linseed supplementation and a relative low proportion of forage in the diet. As mentioned above a low proportion of forage conflicts with strategies to reduce nutrient imports and maintain a healthy rumen ecosystem. In rodents, PUFA also affect intermediary fat metabolism. Thus, besides influencing milk fatty acid composition, feeding PUFA can also influence fat metabolism in dairy cattle.

Animal health It is now well recognised that nutrient metabolism during the periparturient period plays a key role in animal’ performance as well as in reproduction and animal health. At the start of lactation the negative balance between nutrient intake and milk nutrient output is compensated by nutrient mobilisation. The negative balance can be regarded as the consequence of a too low nutrient intake, but can also be regarded as the consequence of a too high mobilisation of nutrients, mainly fat. Fat mobilisation is induced by growth hormone. Reduced sensibility of liver cells for growth hormone, will reduce the secretion of insulin like growth factor 1, which not only reduces feed back for growth hormone release, but also reduces fat deposition. Feeding strategies during the dry period can prevent the reduction in sensibility and subsequently a too high fat mobilisation after calving. Preventing excessive fat mobilisation can be combined with feeding strategies or additives that support periparturient fat metabolism. This may help the animal in coping with an excessive fat mobilisation. Potential additives in this respect can be propylene glycol, choline, and PUFA. Using new research tools, such as nutrigenomics, can be helpful to study the interaction between nutrition and gene and enzyme activities. The outcome of those studies can help us finding new feeding strategies to help the animal to survive this period successfully.

Conclusion Nutrition is one of the main pillars to obtain a sustainable dairy production system in which the interests of the dairy cow, the farmer, the environment and the consumer are combined optimally. Various strategies results in a win-win situation: efficient and effective nutrition will result in healthier cows, less culling, better longevity and consequently lower emissions of minerals and greenhouse gasses. Also the improved fertility at a lower protein level is a win-win situation. However, some goals are conflicting, i.e. feeding lower quality feeds to dairy cows and a reduction in methane production. Farmers and researchers are challenged to overcome these conflicting strategies and to formulate feeding strategies which manage dairy cow metabolism in the desired direction.

Cows’ health and...

- High milk production in early lactation
- Low N / protein input
- Low methane emission
- Low intake of concentrates / cereals
- High secretion of PUFA in milk
- Economic profit

Excessive negative energy balance

- Metabolic disorders
  - Ketosis
  - Fatty liver
- Reproduction
- Immunity

Negative energy balance

**daily**

Nutrient excretion in milk > nutrient intake

- Capacity mammary gland
- High body fat mobilisation
- Mobilisation of body reserves
- High supply to mammary gland
- Stimulate feed intake
- Limit mobilisation

Hormonal control of lipid mobilisation

- Hypothalamus
- Hypophysis
- Growth hormone
- Insulin-like growth factor 1
- Catabolism
- Adipose tissue
- Insulin-like growth hormone releasing hormone
- Liver
- Growth hormone receptor
- Catabolism

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Nutrition in periparturient period

- Fat mobilisation
  - Hepatic GH resistance
  - Hypoinsulinemia
- Liver fat metabolism
  - Oxidation of fatty acids
  - Transport of esterified fatty acids (TAG)

Nutrition in periparturient period

- Farn
  - Energy supply dry period
  - BCS late lactation
  - Supporting supplements after calving
    - Glucogenic nutrients
    - Specific additives
- Research
  - Reduce GH resistance
  - Increase IGF1
  - Adipose tissue, liver, mammary gland

Reproduction

- IGF1 affects gonadotropins
- High feed intake increases hepatic progesterone metabolism
- High protein levels inhibit embryonic development

Nutrition and reproduction

<table>
<thead>
<tr>
<th>Cholesterol</th>
<th>Progesterone</th>
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<tr>
<td>Estradiol</td>
<td>Immune tolerance. uterus inhibit follicle stimulating hormone</td>
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Physiological pathway reproduction changes

- High dry matter intake
- High blood flow to liver
- High estrogen and progesterone metabolism
- Low plasma progesterone
  - Conception rate ↓
  - Pregnancy loss ↑
  - Multiple ovulation (twinning) rate ↑

Relationship protein – reproduction

Wiltbank et al., 2006

Yawonga, 2007

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Nutrition and reproduction

- Field
  - Energy supply dry period
  - BCS late lactation
  - Supporting supplements after calving
    - Glucogenic nutrients
    - Specific additives
  - Milk urea < 40

- Research
  - Reduce GH resistance
  - Increase IGF1
  - Hepatic metabolism of progesterone

Dairy Production in EU

1.5 Mio dairy farmers
22 Mio dairy cows
140,000 Mio kg of milk
In EU25

Protein requirements

Assumptions:
- 1 kg milk = 33 g protein
- Efficiency = 0.25
- 33 million ha of grassland in EU27
- 140,000 million kg of milk
- 4,700 million kg of protein
- Requires 18,700 million kg of feed protein
- Results in 2,200 million kg of N excreted
- Average of 88 kg of N / ha of grassland

Dairy Production in EU

More intensive and more specialised
- Larger herd size, higher production level
- High levels N fertiliser for high yields of high-quality forage
- Application of (N) fertilisers and manure > crop requirements or retention in soil
- If milk yield from 8,700 to 20,500 kg/ha
  N surplus from 376 to 650 kg/ha

N balance dairy farm
N intake has no clear effect on milk N efficiency.

Reducing N intake reduces milk N output!

Approaches
- Low N input
- Protein – energy management in rumen
- Efficient use of absorbed amino acids
- Recycle unused N

Efficiency synthesis essential amino acids

Higher AA supply: lower efficiency

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Nutrition and N utilisation

- Feed
  - Effects of low N input
  - Grassland management
  - Specific supplements
  - Optimise protein utilisation
    - Feed characterisation
    - Milk urea?

- Microbiota
  - Protein evaluation
  - New biomarkers
  - Intermediary metabolism
  - Forage quality
  - Manure characteristics
  - Soil quality

Nutrition and greenhouse gasses

- 50 Mio tonnes CH₄ by ruminant livestock
- 28% of total anthropomorphic emissions
- Loss of digestible energy

Enteric methane abatement

- Replace roughage with concentrate
- Adding lipids
- Replace grass with maize and cereal silages
- Improve digestibility of forages / cell walls
- Additives
  - (essential oils, ionophores, yeast, enzymes)

Enteric methane abatement

- Nutrition
  - In vitro 30%
  - In vivo 10%
- Higher efficiency biomass utilisation
  - Higher production level
  - Longer production period
  - Higher feed efficiency

Nutrition and greenhouse gasses

Omega 3 Fatty Acids and Human Health

Dietary Reference Intake

- 500 mg EPA + DHA per day reduces risk on cardiac death
- 200 mg DHA per day for pregnant women for optimum cognitive development

ALA is no substitute for EPA and DHA

- Conversion ALA to EPA: 5%
- Conversion ALA to DHA: 0.5%
**Whey-protein emulsion gel of soybean and linseed oil**

**Effect of WPEG on FA profile in milk fat**

<table>
<thead>
<tr>
<th>Control</th>
<th>WPEG</th>
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<tbody>
<tr>
<td>FA 12:0</td>
<td>P &lt; 0.05</td>
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</tbody>
</table>

**“Recovery” of supplemented FA**

- **Fatty acid**
  - C18:0
  - C18:2
  - C18:3

  - **supplement** 29%
  - **extra in milk** 21%
  - **extra in milk** 16%

**Increase EPA and DHA in milk**

- Efficiency?
- Milk fat depression
- Quality dairy products

**Conjugated linoleic acid**

- Cis-9, trans-11
- Trans-10, cis-12: Milk fat depression!
- Controlled bio-hydrogenation

**Other effects PUFA**

- Omega 3 suppresses pro-inflammatory status
- PUFA affect hepatic fatty acid metabolism
- Cow health?
Nutrition and fatty acid composition of milk

- Fresh grass: CLA
- Protected fats: PUFA
- Omega 3

Research:
- Controlled biohydrogenation
- Efficiency
- EPA, DHA

Cows’ health and...
- High milk production in early lactation
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Challenges
- Health status
  - BCS end of lactation
  - Nutrition in dry period
  - Support of fat metabolism (glucogenic nutrients, choline, PUFA?)

- Environment – Nitrogen
  - Grassland management at low N input
  - Utilisation of home-grown feeds – by-products
  - Feed characterisation / evaluation
  - Efficient AA incorporation in milk protein

Challenges
- Environment – Greenhouse gasses
  - Methane / Nitrous oxide
  - Production / conservation high quality home grown feeds
  - Feed efficiency

- Milk quality
  - Fresh grass
  - Research to control biohydrogenation and improve FA incorporation into milk fat
  - EPA, DHA