FEEDING STRATEGIES FOR DAIRY COWS

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Milk production is developing heavily in these years, but development differs between countries. In Denmark both total and per cow milk production more than doubled from 1920 to 1950, but without any major rise in herd size. Since 1980, both herd size and milk production increased heavily, with a mean herd size of 134 cows/herd and a mean yield of energy corrected milk of 8994 kg/cow/year in 2010 (**Kristensen et al.,** 2013). This development has required a lot of changes in feeding and management, and therefore also generated a lot of considerations on the feeding strategies for dairy cows.

Based on mainly Danish experience and experiments, the aim of this paper is to discuss strategies for feeding to obtain a robust and efficient milk production with healthy high producing cows.

FEEDING PRINCIPLES

The classical feeding principle is feeding according to yield, this was also the main principle used in Denmark until approx. 1980, and is worldwide also today the most used principle. Based on milk recordings, the cows' energy requirements are estimated. The energy supply by the basal ration (forages or mixed ration) fed either ad libitum or restricted is estimated, and the difference between energy requirements and the supply from the basal ration is then supplied by separately fed concentrate. Amount of concentrate fed can either be equal to the direct calculated requirements, or less or more according to the assumptions used on substitution of basal ration when concentrate offer is increased.

Feeding concentrate according to yield often result in very concentrated rations for high yielding cows, with serious risk of production diseases like acidosis, lameness, liver abscesses etc.. To overcome these problems, and based on a number of production trials, **Østergaard** (1979) proposed the flat rate feeding principle. Using this feeding principle, all cows in early lactation are fed the same constant amount of concentrate, and then have to compensate for higher milk yield by higher intake of a basal ration fed ad libitum. Flat rate feeding requires a high digestible basal ration, either forage or a mixed ration. The period of constant concentrate feeding can be from 12 to 24 weeks, and after this period with constant concentrate feeding, cows are fed concentrate according to yield for the rest of the lactation. The flat rate feeding principle is a very robust feeding principle and it was the most popular principle in Denmark in the eighties and nineties, and fitted well with the loose housing barn systems which nearly fully exchanged the tied up barns in that period.

In the nineties, mixer wagons were introduced in most Danish herds, and total mixed rations (TMR) took over as the most used feeding principle. In the TMR all feed ingredients (forages, concentrates, supplements) are mixed in one mix fed ad libitum. And among TMR herds nearly all herds used the TMR1, meaning that all lactating cows independent of lactation stage and milk yield get the same mix.

These three fundamentally different feeding principles result in quite different distributions of energy to cows within herd, as shown in Figure 1. Where the TMR1 will result in the same energy concentration to all cows independent of lactation stage and milk yield, the individual yield based concentrate offer will result in increased, and the flat rate feeding result in decreased, energy concentration in the ration with increased milk yield and feed intake. The feeding principles, ration restrictions, feed intake prediction and forage availability can vary considerable between countries and these differences can result in large variation in the formulated rations, especially at peak lactation, and are much more important for differences between countries in rations fed to cows than the different energy evaluation systems are.

Today approx. 25% of Danish cows are automatically milked in milking robots (automatically milking systems, AMS). These systems rely on the cows' voluntary visits to the automatic milking unit (AMU). To obtain an acceptable visit frequency, high amounts of concentrate offer is often used as a reward in the AMU. Hereby the AMS has partly set back feeding principles to the individual yield based concentrate feeding, where high amounts of separately offered concentrate might compromise rumen health (**Weisbjerg & Munksgaard,** 2009).

RESPONSE TO ENERGY SUPPLY

Dairy cows respond with an increased milk yield when the energy intake is increased, however with a diminishing response. There are several reasons for the diminishing response. Increased feed intake increase the rate of passage through the rumen, and increased energy intake is normally associated with a decreased forage:concentrate ratio, reducing the cellulolytic activity and thereby reducing the fibre digestibility in the rumen. Increased energy intake will also shift the partitioning of energy towards more weight gain.

The milk production response to increased energy intake (marginal response) depends on cows yield potential (genetic, management) and the quality of forage, and the marginal response increase as yield potential and forage digestibility are increasing. The reason for the effect of yield potential is that cows with high yield potential also have a higher feed intake capacity. Similar do older cows have higher intake capacity than cows in 1st parity (**Weisbjerg & Kristensen,** 2005; **Kristensen et al**., 2003). Therefore, increasing energy density in the ration without proper management, high genetic merit and high forage quality will result in poor milk yield response, low efficiency of energy utilisation and fat cows. Further, a low efficiency of nutrient utilisation can be environmentally harmful.

The above considerations are based on classical additive feed evaluation systems. However, recent meta-analysis on Nordic production trials using energy calculations based on the new Nordic non-additive ration evaluation system Norfor (**Volden,** 2011) have also shown diminishing milk production return to increased energy intake (**Jensen et al.,** 2012).

RESPONSE TO NUTRIENTS

Protein. Lack of protein can severely reduce milk production of dairy cows. Rumen fermentation is dependent on sufficient supply with rumen degradable protein (in the AAT/PBV and NorFor system measured as protein balance in the rumen, PBV), and insufficient PBV supply will hamper fibre digestion, microbial protein synthesis and feed intake.

Beside rumen supply with degradable protein, the cow is dependent on metabolisable protein (in the AAT/PBV and NorFor system amino acids absorbed in the intestine, AAT). AAT originate from microbial synthesis (major supply) and by rumen undegraded feed protein. Insufficient AAT supply reduces milk production and protein concentration in the milk. Increased feed intake and increased forage proportion increase the efficiency of microbial synthesis, mainly due to increased passage rate and washout of microbes. Therefore AAT is normally not limiting milk production in rations which are rich in forage and dense in energy, if the PBV supply is sufficient. Increased AAT supply in rations with high feed intake is an integrated part of the NorFor system (**Volden,** 2011), and also starch + residual carbohydrates proportion of total DM affect efficiency of microbial synthesis in the NorFor system.

Specific essential amino acids might limit milk production however the amino acid (AA) profile of microbial protein is close to optimal for milk production. Therefore increased proportion of AAT origination from microbial synthesis diminishes the risk of lack of specific amino acids, and therefore offering specific (protected) essential amino acids will seldom be beneficial in normal production systems. However, if low rumen degradable protein sources with very unbalanced AA composition are fed, AA composition of AAT should be evaluated, and with severely deficiency in essential AA either supply with protected AA or changes in ration composition should be considered (**Misciattelli et al.,** 2003).

Fat. Fat supplementation above the natural content in ruminant feedstuffs is not essential. However, fat is a energy dense nutrient, and due to a very direct absorption and transport of fatty acids (FA) to the mammary gland via chylomicrons, the energy efficiency of feed FA conversion to milk fat is very high. Further, the very low loss of energy in the form of heat increment in response to feeding supplemental fat make high fat diets interesting for dairy cow herds, where there is a risk for heat stress.

A positive response in milk production is often seen when FA proportion of ration dry matter is increased up to approx. 5%. FA are the energy dense part of fat, and FA proportion of fat determine the value of fat for milk production. FA content, and FA composition regarding as well chain length as degree of saturation heavily differs between feedstuffs and between commercial supplemental fat sources, and due to the direct transfer to the mammary gland, composition of feed FA can heavily affect milk FA composition. Increased supplementation with FA also decrease protein/fat ratio in the milk. Further, medium chain (C12 and C14) and unsaturated FA can impair rumen cellulolytic bacteria and thereby fibre digestion. Therefore, FA composition of supplemental fat should be evaluated according to the effect both on rumen metabolism and on the milk FA composition (**Weisbjerg et al.,** 2008, **Larsen et al.,** 2012, **Weisbjerg et al.,** 2013).

If the goal is maximum production of energy corrected milk, supplementation with FA up to 5-6% of DM can be recommended, however optimal level depend on the fat source, and the more unsaturated the FA are the lower is the optimal level. But fat supplementation will reduce the protein/fat ratio in the milk and affect milk FA composition, and will reduce the DM intake. Due to the negative effect on dry matter intake, supplemental fat feeding in very early lactation should be minimised.

STRATEGIES THROUGHOUT THE LACTATION

Cows nutrient requirement and nutrient supply change markedly during the lactation. Peak feed intake is not reached until 10-20 weeks of lactation for multiparous cows and later for primiparous, and feed intake then stay relative constant until very late lactation (**Bossen et al.,** 2009). Contrarily, peak milk production is reached already 5-6 weeks in lactation for multiparous cows (later for primiparous), and then decrease throughout later lactation. The difference between energy intake and energy requirement either cause live weight loss (mobilisation) or live weight gain (deposition). The lactation period of mobilisation is highly variable and can last for 6-17 weeks for multiparous, and shorter for primiparous cows (**Bossen,** 2007). Live weight change is a reasonable estimate for deposition after minimum live weight has been passed. In first part of lactation live weight changes can severely underestimate mobilisation due to a simultaneous increase in rumen fill. In a recent study rumen fill was found to increase with 34 kg for multiparous cows during the first 5 weeks of lactation, indicating that the extent of mobilisation estimated from live weight registrations were similar underestimated (**Bossen,** 2008).

The mobilisation of 34 kg live weight is equivalent to 544 MJ NE_L at a body condition score (BCS) 2 or 792 MJ NE_L at a BCS 4, as mobilized energy in one kg body is assumed to be higher in the fat cow compared to the thin cow due to a higher fat:protein ratio in the mobilised body mass (BANR, 2001). The underestimation of energy supply from mobilisation using actual live weight as estimate for mobilisation is for BCS 4 approx. equivalent to the NE_L content in 2.7 kg of barley daily for the first 5 weeks postpartum.

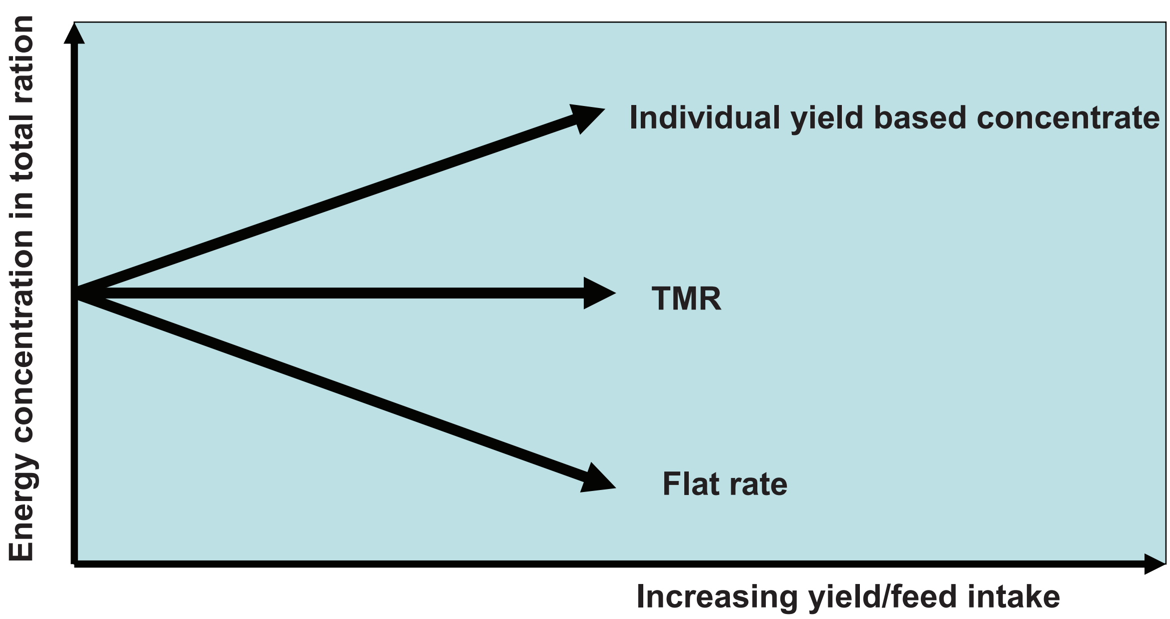

Fig. 1. **Schematic presentation of effect of feeding principle on energy concentration in total ration as affected within herd of individual cow's milk yield and feed intake**

Energy strategies throughout lactation. High lactation yield is dependent on a high peak yield combined with a high yield persistency. High peak yield can be obtained by offering a high energy dense mixed ration in early lactation (**Bossen & Weisbjerg,** 2009). Similar, peak yield can probably be obtained by separate high concentrate supply, but such a strategy will be less robust as separately fed concentrate might reduce total DMI, and increase the risk of acidosis and related production health problems.

Recent results indicate that the metabolic status of mobilisation might be positively correlated to milk yield persistency. A feeding strategy that enables a low extent of mobilisation for a prolonged period therefore might increase lactation milk yield. Such a strategy require a MR2 system (Mixed Ration system with 2 rations with different energy concentrations), and eventually further a separate concentrate feeding to level out the change from high to low energy dense MR (**Bossen & Weisbjerg,** 2009). This persistency strategy keeping cows in a 'close to' mobilisation situation in mid lactation implies the risk that cows can get to lean at the time to dry off (**Bossen et al.,** 2009; **Bossen & Weisbjerg,** 2009). Therefore, using this strategy requires development of 'late lactation fattening strategies' to obtain adequate body condition at dry off on individual cow level. Automatic recordings of live weight could be used for such feed management systems, however, the present high concentrate costs might hamper such strategies. But the rising herd sizes opens for MR? systems with 3 or more mixed rations, where forages could be used more actively in individual (group based) cow strategies.

Nutrient strategies throughout lactation. Although the above mentioned large changes in physiological status during lactation indicate that large differences in specific nutrient requirements could be expected, experimental documentation for this is scarce. Higher AAT requirement could be expected during the mobilisation period, where body mass with high fat/protein ratio is mobilised, and used as energy and protein source. In earlier experiments a higher AAT requirement with fat supplementation to high producing dairy cows in early lactation was not found (**Palmquist & Weiss,** 1994). However, recent studies with abomasally infused casein or amino acid blends to fresh cows have shown large milk yield responses (**Larsen,** 2011).

Likewise, responses to fat supply could be expected to depend on whether cows are in mobilisation or deposition part of lactation, however, literature is not consistent (**Weisbjerg et al.,** 2008). But as mentioned above, fat feeding in very early lactation should be minimised due to the negative effect on dry matter intake, and further it seems problematic for cows to handle a lot of supplemental fat together with the mobilised fat in early lactation (**Weisbjerg et al.,** 2013).

ENVIRONMENTAL IMPACT

Concern on environmental impact of animal production has long been strong in Denmark, and both general legislative restrictions, and restrictions when herds want to expand, challenge the feeding strategies. For nitrogen (N) the concern is on both leaching and ammonia evaporation, for phosphorous on leaching, and for methane on the greenhouse effect. Both P and N feeding in dairy herds has been reduced in Denmark in recent years, and there is potential for further reduction in N feeding without serious risk for reduced milk production (**Weisbjerg et al**., 2012). Methane production is inevitable with the anaerobic fermentation in the rumen, but feeding strategies utilizing forage with higher digestibility and fat supplementation can result in moderate reductions in enteric methane production (**Brask et al.,** 2013a&b).

CONCLUSIONS

The total mixed ration (TMR) is a very robust feeding system, however the TMR1 might be suboptimal. There is probably a large potential for improving yield and nutrient utilisation by supplying energy and nutrients according to lactation stage, and simultaneously to reduce the environmental impact. However, more knowledge is needed to be able to optimise energy and nutrient supply throughout lactation.

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SUMMARY

Milk production is developing heavily in these years. Based mainly on Danish experience and experiments, this paper discusses different feeding principles. Further, dairy cows response to energy and nutrients is discussed. Milk yield response to energy depends on herd yield potential and the forage quality, and response is diminishing with increased energy intake. Milk yield responses to supplemental protein can be large, but oversupply can harm production and negatively impact the environment. Milk yield responses to supplemental fat can be substantial, and can reduce enteric methane production. Strategies for energy and nutrient supply over the lactation have the potential both to increase milk production and to reduce the environmental impact

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