RESEARCH TOPIC REVIEW: Dairy cow nutrition

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1. Scope and Objectives of the Research Topic Review:

The review will consider the recently published information deriving from the Feed into Milk (FiM) programme funded under DEFRA's Link funding programme. It will also draw heavily on data from the various DEFRA funded projects undertaken at the Organic Dairy Herd at Ty Gwyn, Trawsgoed. Data will also be used from the DEFRA funded study run jointly by ADAS, IGER and Abacus Organic Services Ltd. on the Optimising the Production and utilisation of forages for organic livestock. Data from the DARCOF programme in Denmark and from other Scandinavian sources will be included in the review.

It has to be said at the start that the amount of research on nutrition of the organic dairy cow reported over the last 5 years is quite small but hopefully most of it will be included in this review.

Principles of organic livestock feeding require that ruminant diets should be based on organic feeds in the form of a balanced ration that provides for high quality products rather than maximising output. Materials and diets specifically designed to maximise production or to modify rumen function should not be used.

Breeds of animals should be chosen that are adapted to their local conditions, have vitality and are resistant to disease. High genetic merit animals require very high standards of management and very high quality forages in order to maintain their health and vitality. This may be difficult to achieve on a consistent basis..

Organic standards require that forage must comprise at least 60% of the dietary dry matter intake of the organic dairy cow. On many organic farms forage actually comprises significantly more than this. This is in contrast with the conventional dairy cow where there is no lower limit on forage use and where proportion of forage may in some cases be less than 50% of dry matter intake. As a result, the quality of forage on the organic dairy farm is even more important than on the conventional dairy farm. However, because of the minimum forage requirement and the upper limit on concentrate levels (40% of DMI) the organic dairy farmer cannot afford to run out of conserved forage. As many organic dairy farmers make only one cut of silage they tend to go for quantity rather than quality. This, together with the behaviour of grass/clover swards under organic management often results in forages that are low in both energy and protein. While it is relatively easy to balance a deficit of either energy or protein it is much more difficult to balance a deficit of both energy and protein. The behaviour of grass/clover swards under organic management will be considered.

Work on the use of supplementary concentrates, both quantity and type will be reviewed.

Another constraint on organic farmers is that standards do not permit the routine supplementation of diets with trace minerals and vitamins. There is some evidence that forages in some circumstances may be deficient in some trace elements. This will also be considered.

Factors affecting the production and utilisation of forages will also be reviewed as will the implications of forage quality.

2.Summary of Research Projects and Results.

It is appropriate to start this section by summarising the outcomes of a major research project funded under the DEFRA Link programme with the title of Feed into Milk (FiM) A new applied feeding system for dairy cows (Ed. C Thomas, publ. Nottingham University Press 2004). The aim of this project was "to develop a framework and to derive an improved nutritional model that could be applied in advisory practice". The programme derived a new and more accurate prediction of dry matter intake (DMI) based on a number of factors including potential DMI, body condition score, live weight, week of lactation, milk energy output, forage starch intake and concentrate protein intake.

The programme also applies a better understanding of rumen function and has derived a number of new terms including Rumen Stability Value (RSV) and Potential Acid Loading (PAL) which are designed to give warning when diets are either approaching or outside a set of parameters for good rumen function.

The energy requirements of the dairy cow were also revised as the ME system was known to have a number of limitations, in particular it underestimated requirements. As a result, the new system has increased the maintenance requirement by around 5 MJ per day. It has also shown that at low yields energy requirement was underestimated by about 5 MJ/day while at higher yields this increased to around 8 MJ per day as a result of a reduced efficiency of feed conversion.

Protein requirements have also been updated with an increase in daily crude protein intake of 30 gm per day at low yields increasing to around 300 gm per day at an output of 40 litres per day.

There has also been an updating of the description of most of the more common feeds.

All of the factors described above have now been incorporated into a number of revised and highly complex equations to give improved predictions of dry matter intake as well as of energy and protein requirements at different production levels in the form of new computer based feed programmes for the dairy cow.

These are significant revisions and they have considerable implications for the organic dairy cow, particularly as the Standards require a minimum of 60% of the dry matter intake to be derived from forage.

Beaver and Reynolds (1994) stated that the principal sources of energy in forage are derived from water-soluble non-structural carbohydrates and the structural carbohydrates in the cell walls (hemi-celluloses and celluloses). These structural carbohydrates can be extensively digested within the rumen but as the plant matures and the synthesis of lignin increases the rate and extent of digestion decreases.

The supply of sufficient energy in the high forage diets used on organic farms is a major challenge and negative energy deficit has been highlighted as a major problem when conserved forages are fed (Essen et al. 1990., Weber et al., 1993b). Despite the feeding of high forage diets the proportion of energy supplied from forage is often low in UK organic systems with an output of milk from forage of 49.0 – 49.3% (Axient 1999, OMSCO 2001). Nielsen (2001) reported a positive correlation in organic herds between increasing forage quality and higher milk production per cow. A number of trials on both conventional and organic systems have studied the effect of dietary energy on milk quality and animal health (Grieve et al 1986, Duffield et al., 1997, Heur et al., 2000, Weller et al., 2002). The results from these studies show high milk fat to protein ratios, particularly during early lactation, indicating energy deficient diets and the cows suffering from sub-clinical ketosis. Hovi (2002) collated data from 13 organic dairy herds and concluded that cows with a high milk fat to protein ration in early lactation had a reduced reproductive performance, including a longer calving interval.

It is well established that increasing the protein content in the diet leads to an increase in dry matter intake. However, Laven and Drew (1999) have reported that increases in the protein content of diets were correlated with reduced fertility. Horrocks & Vallentine (1999), on the other hand state that nitrogen deficiency in the diet can be a primary factor limiting feed intake while also reducing both the net utilisation of energy in the diet and animal performance. In organic systems where on-farm self-sufficiency in feed is the priority and very high forage diets are fed there is a potential shortfall in protein supply during the winter period (Weller at al., 2002)

Weller and Cooper (2001) examined the protein content of grass and clover in a mixed sward through the season in two consecutive years. They confirmed that the proportion of clover in the sward was relatively low in early season and increased through the season reaching a maximum in August and September before declining. The protein level in the clover was quite high in early season (early May) and increased throughout the season to a high point in October. The protein content of the grass was much lower in early season and whilst it increased throughout the season reaching a high point in October it remained much lower than in the clover. They also showed that there was a difference in protein levels between years 1 and 2. This has some important implications for the organic dairy cow. In year 1 the crude protein content of the sward as a whole was only 13.3% while from early August it was in excess of 21.5%, markedly in excess of requirements even for the freshly calved high yielding dairy cow. The excess was even greater in year 2. This excess of protein has to be eliminated in the form of urea contributing to environmental pollution.

Another important study contributing to our knowledge of organic dairy husbandry has been running at the IGER experimental organic dairy farm Ty Gwyn at Trawsgoed, nr Aberystwyth. Here under Richard Weller's direction there has been an ongoing programme to evaluate two contrasting systems (Weller and Jackson 2006). The aim of one system was to be self sufficient in feed, both forage and concentrates, while the other system was dependent on bought in concentrates. In the first system home produced cereals were used as the sole concentrate at a rate of less than 0.5 tonnes per cow per year while in the second system marginally over 1.8 tonnes of a bought in compound feed was used. The stocking rate of the self-sufficient system was 1.14 LU/ha while that of the bought in feed system was 1.65. Output was much lower in the self-sufficient system at 5,867 kg/cow against 6,967 kg/cow in the bought in feed system, both for a 305 day lactation. The self sufficient system produced a much higher proportion of milk from forage but had a lower efficiency of feed use (MJ of milk per MJ of feed) as a result of the lower yield. They also noted that the biggest challenge was to provide sufficient energy for the cows during the early and mid-lactation periods. A further study by Schiborra et al (2004) in Germany examined the effects of feeding different levels of concentrates through the year. It is interesting to note that in summer when the cows had access to grazing for half the day there was no difference in milk output between the groups despite the second group receiving on average 1.5 kg dry matter from concentrates. However during the winter the group receiving the higher level of concentrates (2 kg/head/day) gave 4 kg ECM. There was no difference between the protein content of the milk between the groups though the group fed the lower level had a slightly higher fat content.

Weller and Jackson (2006) also quoted Austrian and Danish work indicating that with an energy deficient diet there was a higher proportion of milk samples with a high fat to protein ratio and a reduced pregnancy rate in cows fed an energy deficient diet.

The cereals fed at Ty Gwyn were fed dry and while many organic farms do not have acceptable grain storage facilities ensiling could be an acceptable alternative. Adler et al (2005) in Denmark have shown that there is no difference in performance between feeding dried barley and barley ensiled either with molasses or proprionic acid.

Velik (2006) has shown that replacing two thirds of the concentrates with maize silage resulted in a small non-significant drop in milk yield and a small reduction in energy intake. The also showed that the proportion of milk from forage was considerable higher as was the proportion of milk from forage and the efficiency of nitrogen use.

In a study in Denmark, where organic feeding is typically based on home grown feed with a high proportion of roughage Mogensen et al (2003) examined the effects of several different types of concentrate supplementation. The comparison was between a concentrate mix, barley, grass pellets and fodder beet. Feeding the concentrate mix (wheat bran, peas, soya beans, lupins, Lucerne and triticale) resulted in a significantly higher milk yield but with a lower fat content and a higher Energy Corrected Milk (ECM) yield compared with feeding barley. This contrasts with the earlier work of Mogensen and Kristensen (2002) who showed no difference between feeding supplements of rape seed cake and barley. An explanation could be that in the latter experiment a smaller amount of supplement was fed and that protein intake may have been limiting in the former experiment. Feeding grass pellets as the supplement resulted in a lower protein but no change in ECM yield compared to barley. The result of feeding fodder beet was a significantly lower milk yield but no effect on composition. This is contrary to expectation (M J Tame personal observation) but it was acknowledged by Mogensen et al (2003) that the fodder beet had a very high ash content (21% of dry matter) and a very low dry matter (14%) which resulted in an underestimate of energy content perhaps explaining the anomalous results. (The author is not aware of any recent studies specifically relating to this).

As organic standards do not permit the routine use of trace mineral and vitamin supplements it is important that consideration is given to this aspect. Govasmark (2005) has shown that in Norway the relationship between soil and forage trace mineral levels is poor with the exception of zinc. He also concluded that herbage concentration of Fe, Mn, Cu and Mo were sufficient to meet the dietary needs of the ruminant but that Se concentrations were not and the Cu/Mo ratio was generally not balanced. He recommended that in Norway dairy herds should be supplemented with Cu, Co, Se and vitamin E. In Wales Weller and Jackson (2006) compared mineral content of forage from two fields at Ty Gwyn with published data from conventional farms (Whitehead 2000). The values for perennial ryegrass/white clover and for permanent pasture mainly fell within the conventional range with the exception of potassium in the organic permanent pasture which fell below the conventional range and well below the perennial ryegrass/clover sward. However, it should be noted that the range for most trace mineral in the conventional forage is very wide indeed. The organic red clover trace mineral content does give rise to some concern in that Cu, Zn and Se were low. In addition it has been noted by Tame (personal data) that these trace mineral levels are often low in forages grown on certain soils, namely thin soils over chalk and limestone soils. Indeed, the levels were so low in one instance of forages from thin soils over chalk that a number of calves exhibited symptoms of white muscle disease. Measures 2006 (Personal communication) has also noted that Cu and Se supplementation is widespread in the Welsh borders. With regard to mineral supplementation the standards require that forage and soil analyses are used to demonstrate any deficiencies together with blood analyses and any history of previous problems. They also require that the any supplementation targets the deficiency as closely as possible.

In a theoretical study funded by DEEFRA and run jointly by ADAS, IGER and Abacus Organic Services Ltd. (Final report to DEFRA on OF0328 in 2004) the production and utilisation of forages was examined in a number of systems all operating on the same land area. These ranged from a simple all grass system with all concentrate feeds and straw bought in through a range of systems becoming increasingly complex and/or self sufficient. Milk output per ha, stocking rate, and proportion of milk from forage were calculated. For each system three efficiencies of forage utilisation (high medium and low) were examined as were site class and three different concentrate usage levels. The main findings were that efficiency of forage use had a greater effect on output per hectare than either the type of system, the site class or level of concentrate use. The differences in efficiency reflected conservation losses (20, 30 and 40%) and herbage utilisation (85, 75 and 65%). The simplest all grass system dependent on bought in concentrates and straw gave a good level of production per hectare at the highest stocking rate. Systems with either more forages, including high energy forages such as maize and fodder beet, or including cereals and beans but still using some bought in concentrates gave slightly higher levels of production but were much more complex and likely to be more costly as well as having lower stocking rates. Self-sufficient systems with no bought in feeds resulted in low stocking rates and very much lower levels of production putting the farms at a severe economic disadvantage. For a summary of the key data see Appendices 1-3. These appendices are a selection of data which indicate the effects of different systems and different efficiencies of utilisation of forage on total output per hectare and output from forage as well as stocking rate.

One area of current research activity is that of the influence of diet on conjugated linoleic acid (CLA) levels in milk some of which are reported to have beneficial health effects (Aro et al. 2000, Belbury 2002, Baum et al. 2001 and Lock et al. 2004). In the last decade the level of CLA in Dutch milk has declined from 15 mg/g to 7 mg/kg in June/August and 5 mg/g in spring and autumn (Elgersma unpublished results, Ellen at al. 2003). There is also strong evidence of seasonal variation in CLA levels in milk (Mattson 1949, Riel 1963, Auldist et al. 1998, Lock & Garnsworthy 2003) with higher levels in summer pasture fed animals than in winter housed animals fed on conserved forages. It has also been shown that CLA levels in milk are directly related to α-linolenic acid levels in the diet (Elgersma et al. 2003a). In addition, it is now known that α-linolenic acid levels vary between forage type, growth stage, light intensity and nitrogen application (Clapham, et al., 2005, Kliem et al. 2006, Smit 2006). Collomb, et al., (2002) and Lieber, et al., (2005) have shown that diverse highland and mountain pastures showed a higher potential to stimulate CLA in milk than the grasses and legumes of the lowland pasture. Recent work has also shown that while some species-rich pastures may have lower α-linolenic acid levels than rye grass swards the CLA level in milk is not reduced (Lourenco 2005) and it is speculated that rumen hydrogenation may be inhibited by components of the species rich pastures. In addition, Dewhurst et al., 2003a and 2003b suggested that higher levels of CLA in milk and beef on (partial) replacement of grass by clover silages may be related to higher rumen outflow rates on white clover and the presence of lipase inhibitory substances in red clover. However, Ellis et al., (2006) have shown that while PUFA levels are higher in organic milk than in milk from conventionally managed cows there was no difference in CLA or vaccenic acid between organic and conventionally managed cows. Currently, a number of researchers are investigating the role of polyphenol oxidase in promoting CLA levels in milk.

3.Analysis and Conclusions

While organic standards require that dairy cows are fed a diet containing a minimum of 60% forage many herds achieve significantly higher levels than this. As a result, the major challenge for most organic dairy herds is to supply sufficient energy to meet the cow's requirements. There are several aspects to this.

The first is that the Feed into Milk programme has shown that for many years we have been underestimating the dairy cow's requirement for both energy and protein, though a question will be raised with regard to protein later. The second is that on many organic dairy farms only one cut of silage is taken and most farmers put quantity before quality. The result of this is usually grass/clover silages made from swards in which the grass is well past it's heading date with a low digestibility and hence low energy content and often a low protein content resulting in depressed dry matter intakes (Vallentine 1990). So, not only is the energy content of the forage reduced it's intake is also reduced.

While it is relatively easy to balance a moderate deficit in either energy or protein it is very difficult to balance a deficit in both. In extreme cases it may not be possible to satisfy the cows requirements because of constraints on space dictated by the maximum concentrate intake being set by organic standards at 40% of daily dry matter intake. The third aspect is the behaviour of grass/clover swards in organic systems where the protein content in early season can be very low. All these circumstances mitigate against high forage dry matter intakes and constrain the energy intake of the cow.

As a result of the above, there is likely to be a significant energy deficit, particularly in early lactation with a consequent reduction in milk production. If this deficit is too large there is also likely to be an adverse effect on fertility. A number of studies have shown that the higher the energy intake the higher the milk output.

It is therefore vital to make conserved forages of as good a quality as possible. The trouble is that while an earlier cut of silage will address the quality (energy) issue it will exacerbate the quantity and protein aspects. Unfortunately, there is no easy solution particularly on all grass farms relying on either grass/white or red clover swards or permanent pastures for their conserved forages.

There are two possible solutions to the problem. The first is to cut the forage earlier to achieve a higher energy content accepting the reduced quantity and protein content and to make a second cut. The second cut should have a significantly higher protein content to offset, at least in part, the low protein content of the early first cut. While this strategy may be practical in the wetter South West of the country it may not be a good strategy in the drier areas particularly on lighter soils. The second possible solution is to conserve alternative protein crops such as barley with peas, oats/triticale with vetches or cereals with lupins.. Experience in the field suggest that oats/triticale with vetches is a more reliable alternative giving high yields with a protein level in the mid teens, though some trials need to be run to confirm this. In those chalk or limestone areas an alternative would be to grow lucerne or sanfoin for conservation. Early cuts of lucerne may have crude protein levels as high as 22-24%. There is some suggestion that an appropriate mix of legumes could help to overcome low protein levels in swards in early summer for example the inclusion of vetches with grass/red clover swards (Weller & Jackson 2006), though more work needs to be done on the inclusion of vetches and other legumes such as lupins and their contribution to both energy and protein content of conserved forages.

A number of studies have demonstrated the need to provide the lactating dairy cow with a well balanced diet in which the supply of rumen fermentable energy and degradable protein are well balanced (Weller & Jackson 2006., Mogensen & Troels 2003). On those farms producing cereals for feeding to the milking herd in the winter there is a risk of a protein deficit limiting production while in mid-late summer there is a risk, for cows grazing grass/clover swards, of excess protein having an adverse effect on fertility. Mogensen & Troels (2003) have shown that a balanced concentrate mix gave better results than either barley, grass pellets or fodder beet though the fodder beet results here may be anomalous as result of a very high ash content and a very low dry matter. Experience in the UK suggests that there is almost always a positive response to the inclusion of fodder beet. The study of Weller and Cooper (2001) showing that the protein content of grass white clover grazing swards rises to levels well in excess of the requirements of even the highest yielding dairy cow has some serious implications with regard to nitrogen pollution of the environment. The efficiency of nitrogen use by the dairy cow and its incorporation into milk is low (AFRC 1998) and increasing quantities of N will be excreted into the environment. In these circumstances a case can be made for introducing feeds containing low levels of protein such as straw or cereals to try and make better use of the available N and reduce the levels of N excretion. Further, a number of observations (Bax 2004, Tame 1998) indicate that high yielding dairy cows can be maintained on protein inputs as low as 14% in the total diet, though this may well be dependent not only on balancing FME and ERDP but also on balancing their rate of release/breakdown. Further research is needed to verify these observations and to examine the use of low protein supplements to reduce nitrogen excretion of dairy cows grazing grass/clover swards in mid/late summer.

While the trace mineral status of organic dairy herds has received little attention to date what work there is (Govasmark 2005) suggests that there may be a deficit of some trace minerals in Norwegian dairy herds, notably Cu, Zn and Se. Experience in the England and Wales (Measures 2006, Tame 2005) suggests that this may also be the case here. What is clear is that there are very large variations indeed in the mineral content of forages depending on how and where they are grown and that generalisations are inappropriate. Again more work is needed in this area as trace mineral status has a very large part to play in both health (via the immune system) and fertility.

While it may be necessary to change the farming system to provide a better supply of nutrient for the lactating dairy cow the theoretical study on the efficiency of forage utilisation (DEFRA 2004) showed that a greater benefit could be gained in some circumstances from improving the efficiency of forage use than from changing the system. The summary of the work at Ty Gwyn (Weller & Jackson 2006) confirmed the outcomes from the theoretical model showing that milk production/ha was much lower in those systems that are self sufficient in feed for the herd. Milk production is greater from systems growing a range of forages, including high energy forages, but the cost of the increase in complexity of such systems is likely to more than offset the increase in income. Unfortunately, financial aspects were not part of the research brief (DEFRA 2004). However, perhaps the real dilemma is that the system which is likely to be most profitable is one that is not truly sustainable and the system which comes closest to being sustainable is the one conferring the greatest economic disadvantage! In addition, the simplest system is not a particularly stable system in that it is dependent on a single forage and is likely to be subject to the vagaries of the weather etc. The more complex systems are more stable in that the risk is spread over a number of different feeds and while they are still subject to the vagaries of the weather it is unlikely that they will all be adversely affected in the same year. There may also be other benefits from using a much wider range of feeds. Further studies are needed to consider the balance of these factors as well as the financial implications of adopting more complex but more robust and sustainable systems.

While it is suggested above that some CLA’s in milk may be beneficial there is also some evidence that others may be harmful. It is therefore imperative to establish what is currently known about the relative levels and effects of each. The evidence quoted above refers principally to the “beneficial” CLA in milk.

Now that we have some knowledge of α-linolenic acid in a range of forages and herbs and how they respond to growth stage and other factors it may be possible to devise grazing strategies that result in consistently higher CLA levels in milk though there is some work indicating that this may not necessarily be the case. As our knowledge of the role of polyphenol oxidase and other components affecting rumen dehydrogenation in forages increases it may be possible to enhance PUFA and CLA levels in milk not only in grazing animals but also in housed animals fed conserved forages.

Areas for further research are suggested in appendix 4

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