Nutritional management of the high genetic merit dairy cow at grass

The increased utilisation of grazed grass in dairy cow diets offers an effective route in the management of the cost of milk production. On an international scale there is a relationship between an increasing proportion of grazed grass in the diet and a decrease in the total cost of production (Figure 1).

Figure 1: Relationship between total costs of production and proportion of grazed pasture in cows ration.
(Source: Dillon, 2006)

Data from Great Britain also demonstrates that as the total cost of production increases net margin decreases (Figure 2), and that increasing the proportion of milk obtained from forage can reduce total feed costs (Figure 3). This will positively influence overall net margin.

Figure 2: Comparison of total cost of production to net margin in 2011/12.
(Source: DairyCo, 2013)

Figure 3: Proportion of average yield production produced from forage and feed cost.
(Source: DairyCo, 2013)

Therefore there are considerable benefits to increasing the proportion of grazed grass in dairy cow diets. However there can be significant implications in terms of the nutritional management of cows particularly those of high genetic merit (HGM).

The high genetic merit dairy cow

The genetic merit of dairy cows can be defined in different ways, a common interpretation of the term focuses on the production characteristics of an animal including milk, fat and protein yield. It also includes a number of non-production traits and together these can be expressed in
terms of a genetic index to allow comparisons between animals (Figure 4).

Figure 4: Current relative emphasis of traits included in the Profit Lifetime index (PLI) and Production Index (PIN) (inset) (Source: DairyCo, 2012)

This article will focus on HGM dairy cows in terms of selection of production characteristics and the nutritional management of such animals at grass.

HGM animals convert food intake into milk output more efficiently than medium genetic merit dairy cows. This is achieved principally through changes in the partitioning of nutrients rather than food intake or digestive efficiency (Mayne, 1996). This presents challenges in successfully fulfilling the nutritional requirements of the HGM animal at grass. This is because of the increased number of variables particularly in terms of variations in grass nutritional value and intake characteristics.

There is evidence that there are some key biological differences in the gastrointestinal tract between animals of different genotype (Beecher et al., 2014). From the study undertaken by Beecher et al., (2014) if Dry Matter Intake (DMI) is described in relation to total body weight, then at grass there is evidence that HGM (Holstein Frisians) are out performed by other genotypes (Holstein Frisian X Jersey / Jersey) (Table 1).

Table 1 The effect of dairy cow genotype on grass intake in vivo digestibility studies conducted on 4 occasions in 2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>Holstein Friesian</th>
<th>Jersey</th>
<th>Jersey X Holstein Friesian</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake (Kg/d)</td>
<td>16.71</td>
<td>13.93</td>
<td>15.96</td>
</tr>
<tr>
<td>DM intake (kg/100kg of Body Weight)</td>
<td>2.98</td>
<td>3.22</td>
<td>3.09</td>
</tr>
<tr>
<td>OM intake (Kg/d)</td>
<td>14.58</td>
<td>12.42</td>
<td>14.24</td>
</tr>
<tr>
<td>N intake (Kg/d)</td>
<td>0.57</td>
<td>0.47</td>
<td>0.54</td>
</tr>
<tr>
<td>NDF intake (Kg/d)</td>
<td>7.77</td>
<td>6.46</td>
<td>7.49</td>
</tr>
<tr>
<td>ADF intake (kg/d)</td>
<td>4.29</td>
<td>3.58</td>
<td>4.15</td>
</tr>
<tr>
<td>Milk solids (Kg/kg of DMI)</td>
<td>0.093</td>
<td>0.108</td>
<td>0.096</td>
</tr>
</tbody>
</table>

(Source: adapted from Beecher et al., 2014)

Beecher et al, (2014) concluded that the Jersey genotype has greater digestibility and a different rumen microbial population than Holstein Friesian. It was also concluded that the Jersey and Jersey X Holstein Frisian cows had a proportionally greater gastrointestinal tract weight than Holstein Friesians and this was influencing the production efficiencies (milk solids) recorded. It is differences such as these that help to explain why nutritional management of the high genetic merit dairy cow at grass is challenging in comparison to other genotypes.

There are two key factors in achieving the genetic potential of the animal, these include:

- Optimising dry matter intake to successfully fulfil energy requirements.
- Minimising excess body condition loss.
HGM dairy cows carry less condition and lose more in early lactation than animals of lower genetic merit (Figure 5).

**Figure 5** Body condition score (BCS) by day of lactation for three lactations for cows in groups low concentrate control (■), low concentrate select (□), high concentrate control (▲) and high concentrate select (❖).

(Source: Coffey et al., 2003)

Figure 5 demonstrates analysis of Langhill herd data. The Langhill genetic lines have been continuously selected for either kg of fat plus protein (select line), or maintenance of average genetic merit for fat plus protein production in the UK (control line) (Coffey et al., 2003).

The issues around BCS have implications in terms of how successfully animals perform in different types of system. HGM dairy cows managed in a low concentrate grass based systems being more challenging (Coffey et al., 2003). HGM cows are particularly susceptible to losing condition at grass. This is due to the energy requirements increasing faster than intake capacity as potential milk yield increases (Peyraud and Delagarde, 2011). Both grass related and animal factors can combine to create a deficit in energy intake in relation to demand. This leads to utilisation of body reserves (Negative Energy Balance), which is of particular relevance in HGM animals in early lactation.

In terms of nutrient supply to meet the requirements of the HGM dairy cow it would be considered ideal if grazed grass provided a similar nutrient profile to that of a total mixed ration (TMR) diet, allowing an animal to express their genetic potential. There are essential differences between the two types of diet. Pasture for example has a lower DM, however well managed grass has a high feeding value with high ME (11.5-12.5 MJ/kg DM) and CP (300-350 g/kg DM) content (Frame and Laidlaw, 2011). It is the overall feeding value (nutritive value x intake) that is the most important in grazing animals (Dillon, 2006). Grass growth varies over the growing season (Figure 6) this not only influences the quantity available but also the quality. Effective management of grass growth and quality is the foundation of subsequent successful nutritional management. This is principally achieved through operating a rotational grazing system and utilisation of a grass wedge. This allows effective grass quality and surplus/deficit management throughout the season.

**Figure 6** Typical grass growth curve
(Source: DairyCo, 2012)

When contrasting a TMR based system and grass based system there are also differences in the maintenance requirements of the animal under the two types of management, with energy expenditure at grass increasing. Studies have demonstrated that energy expenditure under grazing conditions can
increase by up to 21% (Kaufmann et al., 2011) and subsequently the maintenance requirements should also be increased to account for this (Bruinenberg et al., 2002). This has important implications in HGM animals as this puts further pressure on the balance between fulfilling requirements within the constraint of intake. It also highlights the importance of good farm infrastructure and layout to allow ease of access to pasture if grazing is to be utilised successfully in the HGM dairy cow diet.

The need for supplementation

Studies have indicated that grazing HGM dairy cows that were not fed supplements were unable to achieve the same DMI and level of performance as comparable animals fed TMR (Kolver and Muller, 1998). Kolver and Muller, (1998) reported the grass fed animals achieved a DMI of 19kg/d associated with a milk production of 29.6kg/day. The same study reported that comparable animals on the TMR control diet achieved a DMI of 23.4kg/d with a milk yield of 44.1 kg/d when the appropriately balanced ration was available ad libitum. The study also reported that the grazed animals had reduced milk fat and protein content and lost more body condition. Based on this evidence it supports the conclusion that it is the intake of nutrients that is the first limiting factor in HGM dairy cows consuming high quality pasture.

DMI at grass will be influenced by DM per bite, bite rate and grazing time and these will be affected by sward characteristics. Dillon, (2006) noted that studies have demonstrated that intake and eating rate are restricted by the internal water content of grass (but not external water content). It was described that studies have indicated that 180g DM per kg is a critical level, and below this intake is reduced by 1kg for a reduction in DM content of 40g per Kg. The primary sward factor influencing pasture intake is pasture allowance. Traditionally high stocking rates accompanied by high pasture utilisation formed the basis of high performance from pasture, but this potentially compromised individual animal performance. To maximise pasture intake in high yielding dairy cows it would therefore indicate the objective is to maintain a high pasture allowance (greater than 20kg DM/cow/day above 5cm) within a tall dense sward (Mayne, 1996). It would also follow that the increased grass DM intake requires a lower stocking rate to allow for a higher daily grass allowance (Buckley et al., 2000). However Grazing management designed to maximise individual animal performance is inefficient in maximising pasture utilisation (Peyraud and Delagarde, 2011). Peyraud and Delagarde, (2011) highlighted that lenient grazing in the spring to increase pasture allowance and cow performance results in sward deterioration in mid to late season, increasing the fibrous material present. This will lead to reduced intakes as rumen capacity is reached and rate of passage decreases. Effective sward management early in the spring to increase the green leaf present in the base will improve overall sward quality and digestibility. This will increase pasture intake and help to maintain low residual levels over the whole grazing season (Peyraud and Delagarde, 2011). Therefore managing the HGM dairy cow at grass will require the system to maximise daily herbage intake per cow but also maintain the quantity and quality over the grazing season (Dillon, 2006). It was noted that limiting pasture allowance to 90% of the animals voluntary intake level can be a good guideline to reach equilibrium between per cow and per ha milk production. This can be managed through effective management of pre and post grazing sward height. Ganche et al., (2014) reported that a post grazing sward
height of 3.5 cm should be aimed for in early spring as it allows a balance between high grass utilisation and per-cow production. The challenge in managing the HGM dairy cow at grass is therefore to stop the decline in intake at high levels of animal performance through grazing management (Mayne, 1996).

When managing HGM dairy cows at grass accepting moderate herbage intakes (20-25kg organic matter/cow/day) by reducing pasture allowance and the utilisation of supplementary feeds to achieve total intakes offers a more effective nutritional strategy. A moderate pasture allowance coupled with strategic use of concentrates allocated on a milk yield basis also offers the most cost effective basis of maintaining high yielding dairy cows at grass (Mayne, 1996). Work by McEvoy et al., (2010) concluded that offering a medium mass sward of 1700kg DM/ha and 20 kg daily pasture allowance resulted in increased DMI and milk production. This was in comparison with higher mass swards (2200 kg DM/ha) later in the season.

High production animals are unable to express their genetic merit for milk production on a grass based diet alone, however specific techniques and grazing strategies can be utilised to fulfil the animals nutritional requirements. Milk production greater than 30kg/d without excess mobilisation of body reserves is unlikely without supplementation of additional energy (Kolver and Muller, 1998).

Milk yield response to concentrate supplementation at grass depends on:
- Grass supply
- Grass quality
- Season
- Stage of lactation
- Level and type of supplementation

The efficiency of the supplement is expressed by the increase (kg) in milk output per kg increase in concentrate. Substitution rate is the reduction in herbage DM intake per kg increase in concentrate DM intake. Kennedy et al., (2003) concluded that grass DM intakes of 17kg could be achieved supporting a milk production of 30kg/day under good grazing conditions. Their work also suggests that compared to lower yielding animals, concentrate supplementation of high yielding dairy cows at pasture will result in a lower substitution rate. This ranged from a 0.4kg to 0.6kg reduction in grass DM intake per kg increase in concentrate DM intake. It will also result in a higher milk yield response of >1.0 kg milk/kg of concentrate DM. This is because the animal is unable to fulfil the energy requirement from grazed pasture alone. Adding concentrate supplementation increases energy intake. This will increase rumen fermentation and microbial protein synthesis, which in turn optimises dry matter intake.

The higher grass to concentrate substitution rate of lower genetic merit cows suggests they achieve a greater proportion of their milk production on grass. It also indicates that the grazing appetite of lower genetic merit cows is compromised with the use of supplementary feeding. Dillon, (2006) reported that in a review of the literature up until the early 1990s average substitution rates were around 0.6, with an efficiency of approximately 0.4 to 0.6 kg of milk per kg concentrate DM. It was noted that these studies were undertaken on animals of low to medium genetic merit yielding 15 to 25 kg of milk per cow. More recent studies have demonstrated lower substitution rates and higher efficiencies than previously reported, with an average substitution rate of 0.40 and an efficiency of 0.92 kg of milk per kg of concentrate. It was concluded that the higher response to
supplementation of the high genetic merit dairy cows could be explained by greater nutrient partitioning to milk production than lower genetic merit cows. Further studies such as the review conducted by Bargo et al., (2003) reported that milk production of high producing dairy cows at pasture in early lactation increase linearly. They reported that as the amount of concentrate increases from 1.8 to 10kg DM/day there was an overall response of 1kg milk/kg concentrate. In later lactation there is lower milk response per kg of concentrate.

**Supplementation strategies**

HGM dairy cows should only be fed concentrates with high quality pasture to achieve high performance without the need for high concentrate use (Peyraud and Delagarde, 2011). Forage supplements decrease pasture DMI more than concentrates (Bargo et al., 2003). There is limited information on the effect of type of supplement on performance. Dillon, (2006) reported that energy source (Starch or Fibre) has been shown to have only small effects on intake and milk production at low supplementation rates of 1 to 6kg. However there is evidence to indicate that starch supplementation at grass reduces sub-clinical ketosis and improves ammonia utilisation in the rumen more than fibre supplementation (Pulido et al., 2007).

The Crichton STAR is a useful tool in helping to inform decisions regarding supplementation of the HGM dairy cow at grass (Figure 7). The system takes into account both grazing conditions and animal factors to indicate the likely level of supplementation required. The system involves assessment of seven key areas. Stars are then awarded in relation to defined criteria. Totalling the number of stars achieved from each area will then indicate the level of supplementation required. The scale ranges from 0 to 12+ with the estimated need for supplementation increasing with total number of stars.

An example of the different quantity of concentrate supplementation depending on pasture quality and pasture allowance is demonstrated in table 2. This illustrates the importance of maximising pasture quality to reduce the supplementation required.

**Table 2:** Concentrate supplementation level (Kg DM/day) to meet net energy requirements of un-supplemented grazing multiparous dairy cows varying in Body weight and potential milk yield (kg 4% FCM/day at 20 weeks of lactation) according to pasture quality and pasture allowance (in kg DM/day at ground level)

<table>
<thead>
<tr>
<th>Pasture Quality</th>
<th>Body Weight</th>
<th>400kg</th>
<th>600kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td><strong>Potential Milk Yield</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0</td>
<td>1.3</td>
</tr>
<tr>
<td>Medium</td>
<td>50</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0</td>
<td>3.9</td>
</tr>
<tr>
<td>Low</td>
<td>50</td>
<td>0</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.6</td>
<td>6.5</td>
</tr>
</tbody>
</table>

(Source: Peyraud and Delagarde, 2011)

![Figure 7: The Crichton Star System devised by Dave Roberts at the SRUC Dairy Research Centre. (Source: DairyCo, 2012)](image)
Mattiauda et al., (2013) described that the effect of restricting the period of access to pasture on grazing behaviour, daily DMI and productive performance is poorly understood in dairy cows. Few studies have been conducted assessing access time at pasture whilst maintaining supplementation with silage and concentrates. They reported a decrease in milk yield for cows allowed access to pasture for 4 hours compared to 8 hours, however the cows in the 4 hours group that began grazing later in the morning at 11:00am had slightly higher intakes and higher milk protein yield. Peyraud and Delagarde, (2011) reported that daily access time to pasture can be used to increase grazing efficiency. They reported that the literature has indicated that milk yields generally reduce at low to medium supplementation levels when animals graze for less than 8 hours in a single session. There is also evidence that cows can react to a time constraint at pasture by spending 90% to 95% of the time grazing. This increases pasture intake rate by 30% to 40% compared to full time grazing. It was concluded that to maximise cow behavioural adaptation and grazing efficiency it is recommended to split access time into two sessions of 3 to 4 hours per day. Further recommendations of grazing times in relation to supplementation level and pre grazing sward height are presented in table 3.

Table 3: Recommended minimal access time for grazing dairy cows according to indoors supplementation level and pre grazing sward height

<table>
<thead>
<tr>
<th>Supplementation (forages + concentrates, kg DM/day)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pre-grazing sward height (&gt;8 to 10 cm)</td>
<td>8 to 10 hours</td>
<td>4 to 6 hours</td>
<td>3 to 4 hours</td>
<td>2 to 3 hours</td>
</tr>
<tr>
<td>Low pre-grazing sward height (&lt;8 to 10 cm)</td>
<td>10 to 12 hours</td>
<td>6 to 8 hours</td>
<td>5 to 6 hours</td>
<td>3 to 4 hours</td>
</tr>
</tbody>
</table>

(Source: Peyraud and Delagarde, 2011)

Managing HGM dairy cows in a grazing based system means incorporation of supplementary forage and concentrate feeds. There are differing methods of allocating the different diet components at grazing. Two key strategies include offering a partial mixed ration or forage alone and allocation of concentrates in the parlour. Partial mixed ration is defined as a TMR fed to cattle on a feed pad between bouts of grazing. There are suggestions that separate feeding of concentrates in the parlour separate to the forage supplement could possibly lead to greater fluctuations in rumen pH throughout the day. This will impede fibre digestion and rumen function. However studies have demonstrated that a simple mix of grain and silage has no benefit over traditional strategies of feeding concentrates in the parlour and forage at pasture (Auldist et al., 2013). Feeding partial mixed rations on a feed pad requires careful management of feed space to ensure optimum dry matter intake across the herd. In a study undertaken by Hetti Arachchige, (2014) it was noted that increasing feed space from 0.6 to 0.7 to 1m per cow improved feeding and social behaviour of the animals. It was also noted that the provision of partitions between animals at the feed barrier improved cow feeding activity.

Rumen fermentation at grass

Peyraud and Delagarde, (2011) report rumen pH decreases with an increasing level of intake of grass. This averaged 6.3 at 15kg DM intake and 5.8 at 20kg intake. A corresponding increase in volatile fatty acid concentration was also reported. This rose from 110 to 135 mM/l, with the acetate to propionate ratio declining from 3.4 to 2.6. They reported that other studies have found similar findings. This demonstrates that HGM dairy cows exhibit intensive ruminal fermentation with grasses. This would potentially lead to
concerns over acidosis with reduced rumen function and DM intakes. There is lack of consistency in the effect that concentrates have on ruminal pH of cows supplemented at grass (Bargo et al., 2003). However more recent studies have demonstrated the pH thresholds which cause rumen dysfunction in grain based diets may not be applicable to cows offered grass based diets (McEvoy et al., 2010). McEvoy et al. (2010) reported studies where grazing cows spending 20% of their time with rumen pH values below 5.5 and 10% under 5.0 demonstrated no evidence of disease or production loss. It was concluded that on grass diets the rumen can tolerate a more rapidly changing pH of lower values for longer periods without the negative impact which is associated with grain based diets. This indicates that performance on high quality grass-based diets is not compromised by the low pH levels observed. Peyraud and Delagarde, (2011) suggested this could be related to the lower rates of intake at grazing with frequent meals preventing rapid initial drop in pH and wide fluctuations. It is also suggested that metabolic acidosis could be prevented by the high potassium (K) content of pasture in comparison to maize or cereal silages. Absorption of K increases blood bicarbonate concentration which is partly recycled into the rumen to limit the decrease of pH (Apper-Bossard et al., 2010). There is also evidence that feeds with high degradable protein concentrations such as grass may alleviate pH decline as protein degradation products can neutralise acidity (Dijkstra et al., 2012).

A consistent finding of studies reported by Bargo et al. (2003) is that concentrate supplementation reduces NH3-N levels in the rumen by affecting rumen fermentation. It was suggested that this is likely due to a higher capture of NH3-N from the highly degradable CP of pasture as well as a reduction in total CP intake as energy supplements are usually lower in CP than pasture. Bargo et al., (2003) also suggested high producing animals may require supplementation of a rumen undegradable protein (UDP) source at grass. This is because pasture has a high CP degradability (>70%) and therefore provides lower quantities of UDP than TMR diets. However in the review conducted by Bargo et al., (2003) there are wide variations in the responses reported with supplementation of UDP.

Current research

In order to provide further evidence and understanding of pasture management strategies for high yielding dairy cows DairyCo is currently funding work through a Health, Welfare and Nutrition research partnership. This is lead by the University of Nottingham with Harper Adams University and SRUC. The aims and objectives of the project are:

- To determine factors which influence the behaviour and performance of high yielding dairy cows at grass and to optimise their intake of pasture.
- To determine the effects of timing of pasture access and how this interacts with a buffer-fed TMR on the performance of dairy cows.
- To determine if the age at which dairy cattle are first exposed to pasture (either in their first or second year of age) has any effect on their subsequent motivation to access pasture.
- To provide information on the effects of different supplementation strategies on the performance of grazing cows.

Conclusions

Understanding how to successfully manage the nutritional requirements of the
HGM dairy cow at grass offers both an important route in controlling the total cost of production but also improve overall feed efficiency and mitigation of environmental effects. Research is on-going to aid overall understanding, and the nutritional management techniques required to achieve the genetic potential of the modern HGM dairy cow at grass. Based on current understanding there are however a number of key points to consider:

- High quality pasture and management is the foundation of successful nutritional management of HGM dairy cows at grass.
- The two key factors in fulfilling the genetic potential are optimising DM intake to fulfil energy requirements whilst minimising excessive body condition score loss.
- A balance between pasture utilisation and sward quality must be reached.
- Offer a medium mass, high quality sward to HGM dairy cows.
- HGM dairy cows yielding 30+ litres will require a level of supplementation at grass in order to achieve genetic potential.
- An increase in energy requirement must be factored in depending on herbage availability, digestibility, distances walked, weather and topography.
- Studies have indicated no benefit of offering supplement in a partial mixed ration over traditional in parlour allocation and separate forage.
- There is evidence that the traditional pH thresholds of rumen dysfunction may differ in grass based diets.
- There is evidence that restricting access time to pasture to 3 to 4 hours per session can improve intake.

Overall grass offers significant potential as a cost effective ration component in the HGM dairy cow diet. Achieving this requires excellent grassland management to ensure the nutritional requirements are successfully fulfilled.
References


