

Influence of stocking rate, grazing season length and dairy cow genetic strain on the nitrogen balance of grass based dairy production systems

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Introduction

Stocking rate (SR), grazing season (GS) length and Holstein-Friesian (HF) strain can have a profound effect on the productivity of grass-based milk production systems. The optimum SR is that which gives the maximum sustainable economic output of product per unit area. Increasing SR increases output per ha, but also requires increased inputs of feed and fertilizer. Increasing the proportion of grazed grass utilized for milk production improves the economic sustainability of the system (Dillon *et al.* 2008). Nitrogen (N) use efficiency is one of the key drivers of environmentally and economically sustainable agricultural production systems. Achieving the optimum balance between profitable agriculture and environmental protection is challenging. When production is maximised and output is near equilibrium, all further N inputs are lost to the environment (Rotz *et al.* 2005), and can result in contamination of waters and contributions to greenhouse gas emissions. A N balance model was used to assess the N use efficiency of components of spring calving grass-based dairy production systems; those components being SR, GS length and HF strain.

Materials and Methods

The physical farm input data were obtained from a number of research experiments undertaken at Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland. The strain study consisted of three divergent strains of Holstein-Friesian (HF) dairy cows - high-production North American (HP), high-durability North American (HD) and New Zealand (NZ), managed across a variety of Irish pasture-based production systems - the Moorepark Blueprint system (MP), a high concentrate input system (HC) and a high stocking rate system (HS); giving nine treatments. This study is described in detail by Horan *et al.* (2004) and McCarthy *et al.* (2007).

The grazing season (GS) length experiment had three spring turnout dates (1 February, 21 February and 15 March) and three autumn housing date (25 October, 10 November and 25 November), giving nine treatments. This study is described in detail by Ryan *et al.* (2012).

The stocking rate (SR) experiment consisted of three SRs with three different levels of fertilizer application. The three SRs were 2.0, 2.47 and 2.94 LU/ha. The three annual N fertiliser rates applied to the 2.0 LU/ha treatment were

125, 165 and 205 kg N/ha/year; at the 2.47 LU/ha stocking rate N fertiliser application rates were 165, 205 and 245 kg N/ha/year, and at the 2.94 LU/ha stocking rate the N fertiliser application rates were 205, 245 and 285 kg N/ha/year; giving nine treatments. This experiment is described by Ryan (2011). The Moorepark Dairy Systems Model (MDSM; Shalloo *et al.* 2005) used the grazing management data, sources and quantities of N inputs, and types and quantities of N outputs from each treatment to simulate the performance of the dairy production systems. The production data were then used in a N balance model (Ryan *et al.* 2011) to calculate N use efficiency, N surplus and N loss.

Results

In all experiments, the N input to the systems was primarily in the form of stocking rate (cows/ha), feed, fertiliser and replacement animals. The main N output was N in milk. The N use efficiency of HF strain is largely influenced by replacement rate at a given concentrate supplementation rate. Increasing replacement rate due to fertility issues surrounding seasonal calving systems reduces N use efficiency as a result of increased N surplus (Table 1). Increasing GS length by 30 days increased milk N output by 6%, as a result N surplus per ha was reduced and N use efficiency increased (Table 1). Nitrogen use efficiency per cow was similar across a range of SRs (mean 24.7%). Annual farm gate N surplus per ha increased with increasing SR, however, increasing SR while maintaining fertiliser N input constant increased N use efficiency by approximately 22% (Table 1). The variation in N surplus was greatest between the systems stocked at 2 LU/ha, where production remained similar. Nitrogen use efficiency was greater when SR was increased while N fertiliser application rate remained the same, for example the treatment stocked at 2.47 LU/ha receiving 205 had a greater N use efficiency than the treatment stocked at 2 LU/ha receiving 205 kg N/ha.

Overall increases in N use efficiency and reductions in N surpluses and N losses achieved through selecting appropriate strains for a feeding systems or increasing grazing season length or matching N fertiliser application and stocking rate to match the grass production of the grazing system are individually quite small, as shown in Table 1. However, combining components of grazing systems that reduce N surpluses and increase N use

Table 1. The annual farm gate N surplus per ha and N use efficiency for the strain trial (three strains of Holstein Friesian dairy cows across three pasture based feed systems), the grazing season length experiment (three spring turnout dates and three autumn housing dates) and the stocking rate experiment (three stocking rates with three N fertiliser application rates per stocking rate)

| Strain experiment | | | | | | | | | |
|------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Production system | HS [‡] | | | HC [‡] | | | MP [‡] | | |
| Strain of Holstein-Friesian | HP [‡] | HD [‡] | NZ [‡] | HP [‡] | HD [‡] | NZ [‡] | HP [‡] | HD [‡] | NZ [‡] |
| Total kg N input (kg N/ha) | 324.9 | 322.0 | 320.9 | 381.0 | 378.8 | 377.9 | 323.2 | 321.0 | 319.7 |
| Total N out put (kg N/ha) | 111.4 | 108.8 | 104.5 | 117.2 | 114.3 | 102.4 | 102.8 | 101.3 | 97.1 |
| Nitrogen surplus (kg N/ha) | 213.5 | 213.2 | 216.3 | 263.8 | 264.5 | 275.5 | 220.4 | 219.8 | 222.6 |
| Nitrogen use efficiency | 0.343 | 0.338 | 0.326 | 0.308 | 0.302 | 0.271 | 0.318 | 0.315 | 0.304 |
| Grazing season length experiment | | | | | | | | | |
| Treatment | GS 1 | GS 2 | GS 3 | GS 4 | GS 5 | GS 6 | GS 7 | GS 8 | GS 9 |
| Turnout date | 1 Feb | 1 Feb | 1 Feb | 21 Feb | 21 Feb | 21 Feb | 15 Mar | 15 Mar | 15 Mar |
| Housing Date | 25 Oct | 10 Nov | 25 Nov | 25 Nov | 25 Oct | 10 Nov | 25 Oct | 10 Nov | 25 Nov |
| Total kg N input (kg N/ha) | 275.5 | 274.8 | 275.3 | 274.8 | 275.8 | 275.3 | 274.6 | 275.6 | 276.1 |
| Total N output (kg N/ha) | 79.1 | 80.6 | 79.2 | 78.1 | 72.5 | 80.1 | 76.6 | 72.8 | 75.2 |
| Nitrogen surplus (kg N/ha) | 196.5 | 194.2 | 196.1 | 196.8 | 202.8 | 195.2 | 198.1 | 202.8 | 201.0 |
| Nitrogen use efficiency | 0.287 | 0.293 | 0.288 | 0.284 | 0.263 | 0.291 | 0.279 | 0.264 | 0.272 |
| Stocking rate experiment | | | | | | | | | |
| Stocking rate | 2 LU/ha | | | 2.47 LU/ha | | | 2.94 LU/ha | | |
| Fertiliser N application (kg N/ha) | 125 | 165 | 205 | 165 | 205 | 245 | 205 | 245 | 285 |
| Total kg N input (kg N/ha) | 153.1 | 192.5 | 233.2 | 197.6 | 237.8 | 277.8 | 243.1 | 282.8 | 322.9 |
| Total N out put (kg N/ha) | 63.1 | 61.2 | 61.7 | 75.1 | 80.9 | 82.9 | 82.4 | 93.9 | 89.3 |
| Nitrogen surplus (kg N/ha) | 90.0 | 131.3 | 171.5 | 122.8 | 156.9 | 195.0 | 160.8 | 188.9 | 233.7 |
| Nitrogen use efficiency | 0.412 | 0.318 | 0.265 | 0.380 | 0.340 | 0.298 | 0.339 | 0.332 | 0.276 |

[‡]Pasture-based production systems - Moorepark (MP), high concentrate (HC) and high stocking rate (HS).

[‡]Strain of Holstein-Friesian cows - high-production North American (HP), high-durability North American (HD), New Zealand (NZ).

efficiency would have a big effect on N losses to the environment at a country level.

Conclusion

Although the increases in N use efficiency can be small for individual components of grass based systems, incorporating a number of options can increase the overall N use efficiency of grass based spring calving milk production systems.

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