School of Sustainable Food and Farming

# The potential implications of precision feeding techniques in beef cattle production systems

## Final report

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## 1.0 Study budget

£13,315.80

## 2.0 Introduction

Recent technological advancements, particularly in relation to sensor and communications technologies may provide opportunities to improve animal nutrition, following the example set by other fields such as livestock health and welfare (NASEM, 2016). These new technologies are varied in application, and range from new methodologies for data analysis, to automated feeders and drafting mechanisms (Nkrumah *et al.*, 2006; Deng *et al.*, 2007). Precision feeding or precision animal nutrition techniques utilise these technologies with an aim to optimise nutrient supply for a target level of animal performance, profitability, or environmental outcome (González *et al.*, 2018). The nutritional requirements of beef cattle vary widely according to a number of factors including: developmental stage, production potential, energy expenditure, environmental conditions, and feed characteristics (AFRC, 1993). Precision feeding aims to account for variations in nutritional requirements that occur between animals and over time to increase the efficiency of nutrient utilisation and optimise animal performance, with potential secondary benefits in terms of health and welfare (Kyriazakis and Tolkamp, 2018).

The potential gains associated with precision feeding are not just restricted to the animal, but may have wider implications in terms of environmental impact (Ouatahar *et al.*, 2021). For example, the adoption of precision feeding techniques is likely to increase the efficiency of feed utilisation and mitigate greenhouse gas emissions by reducing methane production (Hristov *et al.*., 2013). Another potential gain is the opportunity to reduce reactive nitrogen emissions which cause air and water pollution. For example, Hou *et al.* (2015) identified positive linear relationships between dietary crude protein concentrations and total nitrogen excretion, when conducting a meta-analysis examining the impact of reducing the protein content in animal feeds. The adoption of precision feeding techniques may therefore facilitate reductions in dietary crude protein concentrations, with associated reductions in nitrogen excretion (Ouatahar *et al.*, 2021).

There is already some evidence to suggest that precision feeding techniques can be applied to manage temporal variability in nutrient intakes (González *et al.*, 2018). Using an in-paddock remote weighing system to monitor steer performance, González *et al.* (2014) reported an opportunity to optimise feed supplementation, and nullify the usual weight loss associated with reduced nutrient intake at pasture during the dry season. It is also hypothesised that between animal variation in nutrient requirements within a group could be better managed by individual feeding facilitated through technologies such as automated drafting mechanisms, or electronic feeders (González *et al.*, 2018). However, Hills *et al.* (2015) reported inconclusive results when reviewing the use of individual feeding in grazing dairy cows. There is subsequently a need to determine if precision livestock feeding techniques can be used to improve the efficiency of feed utilisation and reduce the environmental impact of growing and finishing beef production systems.

## 3.0 Objectives

- To determine the effects of adopting precision feeding techniques on the efficiency of feed utilisation and feed costs in growing and finishing beef cattle production systems.
- To determine the effects of adopting precision feeding techniques on the environmental impact of growing and finishing beef cattle production systems.
- To determine the cost-benefits associated with adopting precision feeding techniques in growing and finishing beef cattle production systems.

## 4.0 Materials and methods

### 4.1 Forage production, animals, housing and experimental routine

The following two experiments were previously undertaken at Harper Adams University between November 2019 and January of 2021.

In experiment 1, 30 Aberdeen Angus x Holstein steers (15) and heifers (15) were fed a typical commercial grass-silage based diet during the winter store period (commencing Autumn 2020). The grass silage (predominantly *Lolium perenne*) utilised in the study, was sourced from the Harper Adams University Farm during the summer of 2020. This crop was harvested following a 24-hour wilt on Monday the 10th of August using a precision chop self-propelled forage harvester, and treated with a silage additive (Axcool, Biotal Ltd at 2.0 litres/T) prior to ensiling in a clamp. The subsequent beef study was undertaken at the Harper Adams University Beef Unit, where the 30 steers and heifers with mean liveweights of 387 and 362 kg respectively, were allocated to a growing diet according to both sex and liveweight. The diet fed consisted of the grass silage plus concentrates, which was formulated to provide a total mixed ration (**TMR**) with a dietary crude protein concentration of 140 g/kg of DM (Table 1 scenario A). This TMR was fed either two or three times per week *ad-*libitum depending upon trough space and aerobic stability. Refusals were weighed back on a weekly basis. The weekly intake of each pen was calculated as the total quantity of feed offered, minus the total quantity of feed refused. The amount of feed offered in subsequent weeks was calculated to be 0.1 more than that which was consumed during the previous week. All cattle were housed at the beef unit in straw bedded yards with five animals per pen. All cattle were weighed at the start of the study, and at 30-day intervals thereafter.

In experiment 2, 45 British Blue x Holstein steers were fed three alternative finishing diets between November 2019 and May of 2020. Two of the diets supplied were forage based where there was a partial replacement of concentrates with whole crop wheat silage (**WCW**) in one instance, and whole crop wheat mixed with red clover silage in another instance (**RC**). The whole crop wheat for they study was produced at Harper Adams University during the summer of 2019. It was harvested on the 25th of July 2019 with a dry matter content of 500 g/kg at approximately growth stage 85 (soft dough). A Kemper header fitted to a self-propelled forage harvester was used to harvest the crop. Prior to ensiling in an Ag-Bag, the whole crop was treated with 2.0 litres/T of the additive Wholecrop Gold (Biotal, Ltd). In contrast, the red clover (*Variety: Atlantis*) utilised in the study, was harvested on the 21st of August 2019 following a 24-hour wilt. Harvesting was undertaken at a dry matter content of 300 g/kg, using a precision-chop self-propelled forage harvester, with the resulting forage being treated with the additive Axcool (Biotal Ltd) at 2.0 litres/T, prior to ensiling in an Ag-bag. The subsequent beef finishing study was undertaken at the Harper Adams Beef Unit where the 45 cattle with a mean liveweight of 459 kg, were allocated by live weight and birth date to one of three dietary treatments (Table 3):

1. Cereal-based concentrate (**Concentrate**)
2. Partial replacement of concentrates with whole crop wheat (631 g/kg DM forage); 369 g/kg DM concentrate (**WCW**)
3. Partial replacement of whole crop wheat with red clover (599 g/kg DM forage; 771:229 whole crop wheat: red clover); 441 g/kg DM concentrate (**RC**)

The concentrate supplements were provided by Wynnstay Ltd as coarse blends, and were based on rolled barley, wheat distillers' dark grains, rapeseed meal, and sugar beet pulp. These were either fed as delivered in the case of the cereal based concentrate, or mixed with the forages to produce a total mixed ration. Cane molasses was also included in the cereal based concentrate diet. The cattle were subsequently housed in straw-bedded yards with five animals per pen. The feeding protocol and associated monitoring of animal intakes was the same as that previously described in experiment 1. Cattle were selected for slaughter by a competent person at fat class 3, with target slaughter weights of approximately 600-650 kg. The cattle remained on the dietary treatments for approximately 7-months until May of 2020 and were processed by ABP Food products, Shrewsbury.

## 4.2 Calculations and statistical analysis

Data from experiments 1 and 2 was subsequently used to investigate the implications of adopting precision feeding in growing and finishing beef cattle production systems under the following scenarios:

- Scenario A (Commercial practice)- The original diets were formulated using predicted animal performance according to AFRC (1993). The initial live weights of the animals were used as the basal point from which all other parameters relating to animal performance were predicted.
- Scenario B (Matched feeding)- Original study diets were reformulated to optimise nutrient supply according to recorded animal performance observed during the experiments. The recorded physical parameters that were introduced into the AFRC (1993) model included: dry matter intake, liveweight, and average daily gain.

Results relating to animal performance and nutrient supply, have been presented in relation to predicted performance (**Scenario A**), performance that was actually recorded on the study as a result of feeding the Scenario A diet (**Recorded performance**), and dietary reformulation as a result of actual performance (**Scenario B**). Resulting changes to diet costs were also modelled, forage costs were derived from the Kingshay Forage Costings Report 2020, and changes to concentrate costs reflect spot prices as taken on the 11th of April 2022. System carbon footprint changes resulting from the different scenarios were also modelled, whereby emissions from imported feed and bedding were calculated from Kool *et al.* (2012), and Martin *et al.* (2016). Cattle enteric emissions were calculated using IPPC (2006) Tier 2 methodology, whilst emissions from manure management were determined according to IPPC (2006) Tier 1 methodology.

# 5.0 Results and discussion

## 5.1 Diet formulation, animal performance, and emissions intensity

It has been hypothesised that precision feeding techniques have the potential to optimise profit, performance, and environmental outcomes in livestock production systems (González *et al.*, 2018). This study is however, the first of its kind to examine the potential implications of precision feeding techniques in United Kingdom (UK) beef cattle production systems. The consequence of adopting matched feeding as a precision technique in either the growing or finishing phases is shown in Tables 2 and 4. The resulting story is very much one of protein oversupply in UK beef cattle diets. The metabolisable protein (MP) system according to AFRC (1993) is the official system for calculating the protein requirements of contemporary beef cattle in the UK, with recommendations generated according to breed type, animal sex, and animal performance. The system itself, is almost 30 years old, and despite its existence, a large proportion of the beef sector continues to express cattle protein requirements in terms of crude protein (CP; AFRC, 1993; AHDB, 2019). All of the growing and finishing cattle diets in this study were formulated according to commercial CP recommendations of 14% DM (Tables 1 and 3; AHDB, 2019). However, when these diets are modelled according to the MP system under scenario A, predicted protein supply is well above requirements, with an MP oversupply across the diets, ranging from 157% for WCW, down to 133% for steers fed the TMR (Tables 2 and 4). Indeed, this situation resides whenever these diets are fed in practice (recorded performance), with a range in protein oversupply of 176% down to 140% across all of the various beef cattle diets respectively.

During scenario B, diets were reformulated to supply the same quantity of metabolisable energy, and therefore sustain the same level of animal performance, but dietary protein concentrations were decreased in line with animal requirements. In both growing and finishing diets, this resulted in the replacement of rapeseed meal and wheat distillers’ dark grains with barley. Despite the removal of bought-in protein sources in all of the diets under scenario B, MP supply still exceeded animal requirements in all instances, but this oversupply was greater in finishing cattle, with a mean oversupply of 137% across the finishing diets, compared to a mean of 109% across the growing diets. The decreased inclusion of bought-in protein sources under scenario B across all of the diets was reflected in a subsequent decrease in the emissions intensity of feed provision, although this ranged from 5% of total emissions for the WCW diet, down to 2.4% of total emissions for the concentrate-based diet respectively. It should however be taken into consideration that there is some debate surrounding the MP requirements proposed by AFRC (1993), with Cottril *et al.* (2009) suggesting an increase in cattle maintenance requirements, although this hypothesis has not been proven *in-vivo*.

The results from this study highlight the potential application of precision feeding techniques to optimise nutrient supply in beef production systems. A large proportion of the beef sector still relies upon crude protein during diet formulation, and a move to the MP system coupled with more accurate prediction of animal intake, has the potential to decrease reliance upon bought-in protein sources and decrease system emissions intensity.

**Table 1.** Raw material and chemical composition of the growing diet fed in experiment 1

| | **TMR** | |
|---|---|---|
| Item[1] | **Scenario A** | **Scenario B** |
| ***Raw materials (g/kg of DM)*** | | |
| Grass silage | 700 | 700 |
| Rapeseed meal | 96 | -- |
| Wheat distillers | 96 | -- |
| Rolled barley | 80 | 272 |
| Molasses (cane) | 10 | 10 |
| Sugar beet pulp | 9 | 9 |
| Min/vits | 9 | 9 |
| ***Chemical composition (g/kg of DM)*** | | |
| Dry matter (g/kg) | 615 | 611 |
| Crude protein | 141 | 94 |
| ERDP (0.5) | 97 | 67 |
| DUP (0.5) | 17 | 12 |
| Ether extract | 30 | 23 |
| Ash | 73 | 67 |
| Neutral detergent fibre | 490 | 463 |
| Starch + sugars | 96 | 193 |
| ME (MJ/kg of DM) | 10.3 | 10.3 |
| FME (MJ/kg of DM) | 8.5 | 8.5 |
| ERDP/FME | 11.5 | 7.7 |
| MP (<10.0; g/kg of DM) | **79** | **54** |
| MP (>10.0; g/kg of DM) | 71 | 67 |

[1] ERDP: Effective rumen degradable dietary protein; DUP: Digestible undegraded protein; ME: Metabolisable energy; FME: Fermentable metabolisable energy; MP: Metabolisable protein

**Table 2.** Effect of matched feeding on the performance, nutrient balance, and emissions intensity of Aberdeen Angus cross Holstein steers and heifers during the housed growing phase.

| | Steers | | | Heifers | | |
|---|---|---|---|---|---|---|
| | **Scenario A** | **Recorded performance** | **Scenario B** | **Scenario A** | **Recorded performance** | **Scenario B** |
| Initial live weight, kg | 387 | 387 | | 362 | 362 | |
| Final live weight, kg | 461 | 497 | | 429 | 476 | |
| Mean live weight, kg | 424 | 442 | | 396 | 419 | |
| Housed period, days | 70 | 70 | | 70 | 70 | |
| ADG[1], kg/d | 1.05 | 1.56 | | 0.95 | 1.62 | |
| Dry matter intake, kg/d | 8.86 | 11.09 | | 8.41 | 10.89 | |
| Feed conversion ratio, kg/kg | 8.44 | 7.09 | | 8.85 | 6.74 | |
| MP[2] requirement, g/d | 459 | 561 | 561 | 409 | 532 | 532 |
| MP supply, g/d | 630 | 789 | 601 | 598 | 775 | 590 |
| MP supply as a % of requirements | 133 | 140 | 107 | 146 | 146 | 111 |
| Diet cost, £/T of DM | 165.64 | 165.64 | 137.27 | 165.64 | 165.64 | 137.27 |
| Diet cost, £/kg of ADG | 1.40 | 1.18 | 0.98 | 1.47 | 1.12 | 0.92 |
| ***Emissions intensity, kg$CO_2$-eq/kg of ADG*** | | | | | | |
| Feed | 4.88 | 4.11 | 3.69 | 5.12 | 3.90 | 3.50 |
| Enteric | 4.53 | 3.82 | 3.82 | 4.76 | 3.62 | 3.62 |
| Manure and bedding | 5.85 | 3.94 | 3.94 | 6.47 | 3.80 | 3.80 |
| Total | 15.27 | 11.87 | 11.45 | 16.35 | 11.32 | 10.92 |

[1] Average daily gain

[2] Metabolisable protein

**Table 3.** Raw material and chemical composition of the finishing diets fed in experiment 2.

| | Concentrate | | WCW | | RC | |
|---|---|---|---|---|---|---|
| Item[1] | **Scenario A** | **Scenario B** | **Scenario A** | **Scenario B** | **Scenario A** | **Scenario B** |
| ***Raw materials (g/kg of DM)*** | | | | | | |
| Whole crop wheat silage | -- | -- | 631 | 631 | 462 | 462 |
| Red clover silage | -- | -- | -- | -- | 137 | 137 |
| Rolled barley | 716 | 821 | 85 | 326 | 212 | 336 |
| Sugar beet pulp | 112 | 112 | 14 | 14 | 33 | 33 |
| Rapeseed meal | 53 | -- | 120 | -- | 62 | -- |
| Wheat distillers | 54 | -- | 121 | -- | 62 | -- |
| Molasses (cane) | 43 | 43 | 13 | 13 | 14 | 14 |
| Min/vits | 22 | 22 | 16 | 16 | 18 | 18 |
| ***Chemical composition (g/kg of DM)*** | | | | | | |
| Dry matter (g/kg) | 863 | 861 | 594 | 591 | 543 | 542 |
| Crude protein | 141 | 116 | 140 | 102 | 140 | 122 |
| ERDP (0.5) | 103 | 86 | 97 | 71 | 99 | 86 |
| DUP (0.5) | 20 | 18 | 19 | 15 | 17 | 15 |
| Ether extract | 24 | 21 | 25 | 21 | 22 | 20 |
| Ash | 59 | 55 | 61 | 56 | 70 | 67 |
| Neutral detergent fibre | 239 | 223 | 453 | 428 | 429 | 417 |
| Starch + sugars | 417 | 471 | 222 | 307 | 201 | 241 |
| ME (MJ/kg of DM) | 12.8 | 12.8 | 10.8 | 10.8 | 10.9 | 10.9 |
| FME (MJ/kg of DM) | 12.3 | 12.4 | 9.2 | 9.4 | 9.4 | 9.5 |
| ERDP/FME | 8.4 | 6.9 | 10.5 | 7.5 | 10.6 | 9.1 |
| MP (<10.0; g/kg of DM) | **86** | **72** | 81 | **60** | 80 | **70** |
| MP (>10.0; g/kg of DM) | 98 | 97 | **78** | 75 | **77** | 76 |

[1] ERDP: Effective rumen degradable dietary protein; DUP: Digestible undegraded protein; ME: Metabolisable energy; FME: Fermentable metabolisable energy; MP: Metabolisable protein

**Table 4.** Effect of matched feeding on the performance, nutrient balance, and emissions intensity of British Blue cross Holstein steers when fed either a concentrate or whole crop wheat-based diet during the finishing phase.

| | **Concentrate** | | | **WCW** | | |
|---|---|---|---|---|---|---|
| | **Scenario A** | **Recorded performance** | **Scenario B** | **Scenario A** | **Recorded performance** | **Scenario B** |
| Initial live weight, kg | 458 | 458 | | 459 | 459 | |
| Final live weight, kg | 652 | 652 | | 652 | 652 | |
| Mean live weight, kg | 555 | 555 | | 556 | 556 | |
| Finishing period, days | 118 | 134 | | 138 | 139 | |
| ADG[1], kg/d | 1.65 | 1.45 | | 1.40 | 1.39 | |
| Dry matter intake, kg/d | 9.65 | 9.37 | | 12.18 | 12.16 | |
| Feed conversion ratio, kg/kg | 5.85 | 6.46 | | 8.70 | 8.75 | |
| MP[2] requirement, g/d | 616 | 581 | 581 | 572 | 570 | 570 |
| MP supply, g/d | 827 | 826 | 697 | 897 | 948 | 734 |
| MP supply as a % of requirements | 134 | 142 | 120 | 157 | 166 | 129 |
| Diet cost, £/T of DM | 353.35 | 353.35 | 337.92 | 235.18 | 235.18 | 200.53 |
| Diet cost, £/kg of ADG | 2.07 | 2.28 | 2.18 | 2.05 | 2.06 | 1.75 |
| ***Emissions intensity, kg$CO_2$-eq/kg of ADG*** | | | | | | |
| Feed | 2.83 | 3.13 | 2.91 | 3.64 | 3.66 | 3.00 |
| Enteric | 1.45 | 1.60 | 1.60 | 4.67 | 4.70 | 4.70 |
| Manure and bedding | 3.75 | 4.27 | 4.27 | 4.42 | 4.45 | 4.45 |
| Total | 8.03 | 9.00 | 8.78 | 12.73 | 12.81 | 12.16 |

[1] Average daily gain

[2] Metabolisable protein

**Table 5.** Effect of matched feeding on the performance, nutrient balance, and emissions intensity of British Blue cross Holstein steers when fed either a red clover-based diet.

| | **RC** | | |
|---|---|---|---|
| | **Scenario A** | **Recorded performance** | **Scenario B** |
| Initial live weight, kg | 462 | 462 | |
| Final live weight, kg | 648 | 648 | |
| Mean live weight, kg | 555 | 555 | |
| Growth period, days | 124 | 139 | |
| ADG[1], kg/d | 1.50 | 1.35 | |
| Dry matter intake, kg/d | 11.92 | 12.84 | |
| Feed conversion ratio, kg/kg | 7.95 | 9.51 | |
| MP[2] requirement, g/d | 590 | 563 | 563 |
| MP supply, g/d | 917 | 988 | 905 |
| MP supply as a % of requirements | 155 | 176 | 161 |
| Diet cost, £/T of DM | 228.41 | 228.41 | 210.59 |
| Diet cost, £/kg of ADG | 1.82 | 2.17 | 2.00 |
| ***Emissions intensity, kg$CO_2$-eq/kg of ADG*** | | | |
| Feed | 3.13 | 3.74 | 3.37 |
| Enteric | 4.27 | 5.11 | 5.11 |
| Manure and bedding | 4.12 | 4.58 | 4.58 |
| Total | 11.52 | 13.43 | 13.07 |

[1] Average daily gain

[2] Metabolisable protein

## 6.0 Progress against milestones

**Table 6.** Milestones and achievements

| **Project milestones** | **Initial completion date** | **Completion status** |
|---|---|---|
| Start to model various scenarios | October 2021 | Complete |
| Completion of the cost-benefit analysis | Revised to April 2022 | Complete |
| Prepare final report | Revised to May 2022 | Complete |

## 7.0 Achievements and potential outputs

- Final report provided for publication on the School of Sustainable Food and Farming website- May 2022

- Evidence of protein oversupply in the current study has been used to generate a low protein hypothesis currently being tested at one of Morrisons producers- In process

- One abstract for publication at the British Society of Animal Science- Target completion date of April 2023

- Target of one peer-reviewed publication which examines the potential of precision feed techniques in beef production systems- Target completion date of May 2023

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