THE EFFECT OF A BYPRODUCT DIET ON THE PERFORMANCE OF DAIRY COWS IN THE UK

Sub theme: The Role of Policy in Defining Future Farming Systems

M.D. March[1], R. Wilson[2], J. Flockhart and D.J. Roberts

[1]SRUC Research, West Mains Rd, Edinburgh, EH9 3JG

[2]University of Edinburgh, School of Geosciences, EH9 3FE

Abstract:

The performance of two intensive dairy farming systems is investigated by comparing production, health and financial indicators from continuously housed herds of Holstein Friesian cows. One herd were fed a total mixed ration containing approximately 4.0 tonnes of concentrate and low forage (LF) components. The additional herd were fed solely by-product (BP) feedstuffs which were non-human edible and included no forage components except straw. This by-product and industry waste based ration generated 5% fewer greenhouse gas emissions and required 25% less land. However, the BP diet was more expensive per tonne than the ration containing forage components. Results show this complete by-product diet had negative effects on milk composition which could lead to loss of income for the farmer through penalties for reduced butterfat. Body condition score attributed to the low forage herd was, on average, higher and healthier than the cows consuming by-products. This work suggests that in order to deliver a profitable housed dairy enterprise alongside meaningful emission or land use reductions, trade-offs should be considered and milk quality maintained.

Keywords: dairy system, housed, production, financial, environment

1. Introduction

The European dairy industry has seen transformations in recent years and whilst the global outlook for dairy markets indicates growth of at least 100 billion litres by 2020 (Fonterra, 2012) high milk prices have not been sustained worldwide, and in the UK volatility continues. As well as variations in supply and milk prices, changes in animal yields has typified the UK, where between 2004 and 2014, average yield increased from 6763 to 7912 litres/cow/year (AHDB, 2016). Over the decade to 2014, there has been a reduction of 36% in the number of UK dairy farms from 21,616 to 13,815, and the average herd size in the UK increased from 97 to 142 cows (AHDB, 2015).

Changes to UK distributions of dairy farm numbers, herd sizes, yields and management methods may have incorporated alterations to feeding strategies. One survey reported that only 33% of dairy farms in Britain now graze all their cows during the summer months without any housing while 8% were housing all milking cows all year round (March *et al.*, 2014). Low milk price has helped generate increased interest in maximising grazing and home-grown feeds from some farmers, whilst others are housing their cows all year round and feeding them a complete diet containing a high proportion of imported feeds. Changes in dairy herd structures have been reported in the EU15 where the total number of dairy farms fell by 19% between 2009 and 2014 (AHDB, 2015a). In New Zealand (NZ), between 2000 and 2011 the proportion of both high input and medium input systems doubled, while low input systems nearly halved (Morrison, 2013). A high production system in NZ could be described as using greater than 30% imported feeds throughout lactation (Dairy NZ, 2016).

A need to move towards more efficient food production systems that deliver increased outputs whilst appropriately utilising resources and improving ecosystems (Garnett, 2014) may require farmers to provided further data on their environmental performance. Indeed, strategies to reduce greenhouse gas (GHG) emissions can be supported by carrying out farm carbon footprints and these could potentially become a mainstream calculation. A need to reduce GHG emissions within agriculture combined with debate surrounding the use of human edible cereals within ruminant diets, has led to calls for dairy cows to be fed on wastes or by-products (Garnett, 2009).

There are few reports of comparisons between UK housed dairy systems undertaken on the same farm with strict management rules and this paper describes management and health performance as well as financial indicators stemming from two diets offered to two genetic merits of cows. The results are intended to provide an overview of the dairy systems and to convey practical information, production and financial outcomes stemming from limited forage and by-product feeding regimes.

2. Methods

Studies were undertaken with cows belonging to the Langhill pedigree herd based at the SRUC Dairy Research and Innovation Centre, Dumfries, Scotland between 2006 and 2015. This Select (S) group of cows were sired by bulls with high predicted transmitting abilities (PTA) for fat plus protein yield (Pryce *et al.*, 1999). Cattle from the two trials were managed according to the same rules and each regime was designed to allow animals to express their potential for milk production within the limitations of the rations offered. Here we compare results from the housed systems with reporting periods of April 2006-2010 for the Low Forage (LF) system, and April 2012-2016 for the by-product (BP) system.

During both trials cows were milked thrice a day and housed in the same building with cubicles, concrete passageways and automatic scrapers. Cattle were fed a complete diet offered as a total mixed ration (TMR) irrespective of milk yield and stage of lactation. Sub-groups alternated, every 3 days, either between being fed through Hoko gates (Insentec BV, Marknesse, The Netherlands) which recorded individual feed intake or being fed as one group. The forage components of the complete diet for the LF system consisted of home-grown grass silage, maize silage and whole crop wheat alkalage, however, within the BP system the only non processed feedstuff consumed was chopped straw. Fresh weight (FW) and dry matter (DM) proportions of the complete diets are provided in Table 1. LF cows were fed 0.6 kg/day fresh weight of a standard concentrate whilst in the milking parlour. Cows were dried off eight weeks prior to estimated calving date and consumed a straw based diet and after four weeks were fed a transition diet which consisted of 30% of the average daily dry matter intake of appropriate milking cow ration.

Table 1. Constituents and proportions of the Low Forage and By-product diets

Diet	Foodstuff	FW[1] Diet Proportion	DM[2] Diet Proportion	DM Content	Cost / Tonne
Low forage	Wheat Grain	0.10	0.16	0.88	£122
	Sugar beet pulp molassed	0.08	0.13	0.89	£160
	Soya bean meal	0.07	0.12	0.91	£320
	Wheat distillers grains	0.03	0.06	0.91	£210
	Soya hulls	0.01	0.02	0.88	£143
	Sopralin	0.01	0.01	0.85	£600
	Grass silage	0.44	0.28	0.33	£25
	Maize silage	0.18	0.09	0.27	£33
	Wheat alkalage	0.07	0.09	0.67	£41
	Rumen protected fat	0.01	0.01	0.95	£600
	Minerals/vitamins	0.01	0.01	1.00	£600
By-product	Chopped straw	0.20	0.23	0.82	£60
	Sugar beet pulp molassed	0.17	0.21	0.89	£160
	Breakfast cereal	0.10	0.13	0.91	£171
	Moist distillers grains	0.25	0.09	0.28	£66
	Biscuit meal	0.07	0.09	0.91	£120
	Distillers grains (Wheat)	0.07	0.09	0.91	£210
	Soya bean meal	0.07	0.09	0.91	£320
	Molasses Cane	0.06	0.06	0.65	£188
	Rumen protected fat	0.01	0.01	0.95	£600
	Minerals/vitamins	0.01	0.01	1.00	£600

[1]FW= Fresh Weight, [2]DM=Dry matter

Yields from individual cows were recorded at each of the thrice daily milkings and samples were taken weekly for analysis of fat and protein. Live weights were measured daily while body condition score (BCS) and locomotion score (LCS) were assessed weekly using 1-5 scales (Mulvanny, 1977). Cows calved all year round and at the end of their 3rd lactation were transferred to a separate commercial herd.

Data

Production and health variables were extracted from the database which held individual cow records and these were grouped at system level and sorted by year. Weekly fat and protein levels were averaged per cow and yields were expressed in terms of energy corrected milk (ECM) by applying the following formula (Sjaunja *et al.*, 1990) (Equation 1):

ECM = 0.25*Milk (kg) +12.2*Fat (kg) + 7.7*Protein (kg) (1)

Daily DM feed intakes were calculated from cow FW intakes and the DM's of the TMR samples and averaged monthly for each system. Herd inventories were evaluated monthly to account for the number of cows in milking, dry and transition groups. Individual food intakes relating to dry and transition cows were not measured and quantities were calculated from daily ration allowances. Weekly BCS's and LCS's for all milking cows were averaged at system level annually and were partitioned by lactation.

Gross margin analysis was undertaken to provide an outline financial comparison of the two feeding regimes to directly compare income from milk and cattle sales and costs stemming from the diets. Feed components contained within each of the diets were costed with average industry values for October 2016 and are shown in Table 1 (pers. com Karen Stewart, SRUC). Total feed costs in each group were estimated by cost per tonne of TMR for the LF and BP diets and calculating at herd level depending on an average daily intake per cow. The estimated cost for each diet was £88 and £139 per tonne for LF and BP systems respectively. A standard liquid based schedule was applied to monthly output from each system with a base value of 23.0p/land bonuses or penalties applied for constituent levels, in this case with minimums of 37.0g/kg of butterfat and 30.0g/kg of protein. Payments for hygienic quality as well as a volume bonus were applied at £0.034 and £0.006 per litre produced.

Heifers were imported onto the farm at a cost of £1,600. Bull calves were sold for £20, heifer calves were sold for £80 and dead calves had zero value. Cull cows leaving the systems were sold at £600. Veterinary and medical costs as well as artificial insemination (AI) expenses were allocated per cow at a cost of £105 and £50 respectively. System average milk yields were applied (Table 3) and to allow a system comparison assumptions utilised were, an equal herd size of 50 cows, and replacement rates 30% for a S genetic merit.

Annual carbon footprints stemming from each of the dairy systems were estimated using SAC's PAS (2050) based agricultural resource efficiency calculator. AgRECalc is a sustainable farming tool which determines whole farm carbon footprints using IPCC Tier 1 and Tier 2 methodology in order to provide benchmarks and key performance indicators of a farm enterprise. Data were entered annually at system level and results expressed per kg of output (meat and ECM). To represent the necessity of a landless system with a BP diet to remove slurry from the farm, this system was modelled as exporting 100% of manure. In reality a proportion of the slurry was exported whilst an amount remained on farm to provide nutrients for an alternative dairy system.

Results

Key production indicators and average annual outputs for the dairy systems are outlined in Table 2. Average yields per cow of 10,130kg and 10,255 kg within the LF and BP diets both exceed the current UK mean yield of 7,912 litres (AHDB, 2016). When the constituents of milk are considered, cows consuming the LF diet produced an average of nearly 500kg more ECM per cow. Table 2 shows that, on average, annual fat percentages obtained within a BP diet were reduced by 0.4 when compared a LF diet, while protein percentages decreased by 0.1. UK averages for butterfat and protein are 4.0 and 3.3 respectively (AHDB, 2017). This suggests feedstuffs within the BP ration did not provide appropriate precursors for milk constituents.

Table 2 Annual production indicator averages for LF and BP feeding systems

	Low Forage	By-product
Total yield (kg)	476104	543522
Total yield (ECM)	470541	505792
Herd size	47	53
Yield / cow (kg)[1]	10130	10255
ECM yield / cow (kg)	10012	9543
Butterfat %	3.9	3.5
Protein %	3.3	3.2
Body weight (kg)	651	663
Daily yield (kg)	36.0	34.6
DMI (kg)	19.8	20.3
Age at first calving (days)	769	744
Calving interval	411	383
Locomotion score (LCS)	2.2	2.4
Body condition score (BCS)	2.2	2.0

[1]Milk yield not standardised to 305 day lactation

Gross margin evaluations were carried out to by considering income from sales of milk and livestock and the variable costs associated with production such as feeding, veterinary and livestock expenses. Results show a range of variable costs and potential incomes depending diet and highlight explicitly why high yields do not guarantee maximum profits (Table 3). The BP group generated the greater income from liquid milk sales, however lower quality milk equated to penalties for below minimum fat content and thus the LFS generated the highest overall total income.

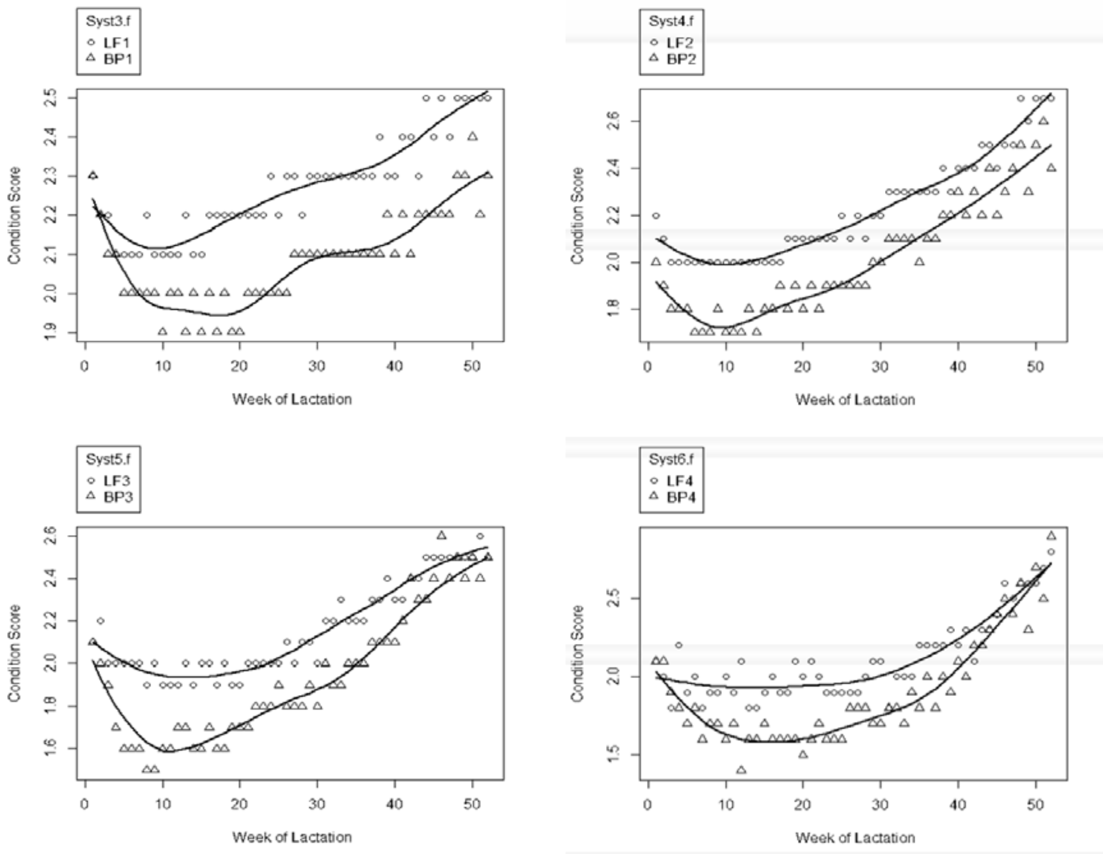
Costs were greatest within the BP system because of the price of components within the TMR. Modelled income for the BP system would be improved if all slurry exported was sold with a financial value that was equivalent to manufactured fertiliser. The estimated value of slurry produced by BP group was £6,097 which could increase money coming in however it would not be sufficient to offset penalties from poor composition and high feed costs.

Table 3 Financial indicator averages for Select merit cows within LF and BP feed systems

Income/Cost	Low Forage	By-product
Income milk sales @ 23p/l	£119,988	£121,472
Fat adjustment	£1,271	-£4,264
Protein adjustment	£2,015	£1,767
Cull cows & calf sales	£10, 750	£10,750
Total Income	**£134,025**	**£129,725**
Total income p/l	£0.257	£0.246
Total income /cow	£2,680	£2,594
Feed costs	£40,871	£63,103
Vet Med & AI	£7,000	£7,000
Livestock expenses	21000	21000
Total variable costs	**£68,871**	**£91,103**
Gross Margin	£65,155	£38,622
Gross Margin as % Income	49%	30%

Herd health indicator averages were calculated for each system to evaluate whether moving from a low forage diet, to a by-product based diet led to any changes in the wellbeing of the animals (Table 2). BCS's ranged from 0.5-4.0 for cows in the BP system and from 0.75-4.25 for cows the LF system. Further investigation highlighted that on average, across each of the four lactations, body condition scores within the BP group fell to a lower level than those in the LF group. Figure 1 illustrates differences in condition score minimums and ranges between feed systems and as lactations progress. Locomotion scores ranged from 1-4 in the LF system and from 1-5 for in the BP system.

Figure 1. Average BCS's for LF and BP across lactations 1-4



When compared to a LF diet, with no need for forage to be grown on farm, it is estimated that the BP system required 28% less land use per livestock unit (LU) when applying a mass balance allocation approach. Replacing grass silage, maize silage and wheat alkalage with biscuit meal, breakfast cereal, dark grains and chopped straw generated fewer emissions because allocation factors for by-products are lower. Similarly, per kg of output of ECM and meat, estimated carbon footprints are less within a BP diet than a LF ration. This could be expected because of the nature of by-products and no requirement for on farm fertilisers. A BP system may also attract fewer emissions because all slurry would be exported from the farm, however poor quality milk output may diminish potential gains.

Table 4 Resource use indicator averages for a Select merit within LF and BP feed systems

	Low Forage	By-product
Land area - on farm	26.4	0
Land area - off farm	30.2	45.1
Total land area	56.6	45.1
Land area / LU	1.21	0.87
Kg CO_2 / kg output	0.83	0.79

Discussion

The objective of this work was to compare a novel BP diet alongside a more conventional concentrate based ration, within housed dairy systems. Key annual statistics derived from each of the four feeding regimes have shown that whilst both diets have the ability to produce above UK average yields, it is important to consider a range of indicators to assess the overall performance of the systems from a variety of perspectives. Depending on focus area, a BP diet may provide advantages with respect to land use and lower carbon emissions, albeit with the caveat of manure exportation, however milk quality has an influence on environmental and financial indicators. Availability of BP ingredients in the diet discussed here would be possible nationally however there could be higher costs for some ingredients depending on the distance of haulage from source.

It may be fair to question the appropriateness of a solely BP diet unless issues of low quality composition and financially unviable manure exportation could be resolved. Low butterfat contents can arise for more than one reason and in this case resulted in a 0.011ppl difference in BP milk income compared to the LF system. If the roughage proportion in the cow's ration drops, then lower butter-fats can be a typical response (McDonald *et al*, 2011b). When turning cows out to graze spring grass, a method to minimise the anticipated drop in butterfat would be to feed a buffer feed high in long fibre, after milking, or in feeders in the field. Changing calving pattern would be a longer-term approach to even out the content and yield of butterfat and achieve a more consistent milk price. Butterfat and protein levels could potentially be improved with the addition of alternative feed components however experiment continuity rules would not allow this.

Decreased milk quality results in the BP system, corresponded with lower average herd BCS's across all lactations when compared to the LF system. BCS is a subjective measure of fat reserves which can be used as a management tool to monitor the health and productivity of the herd (Pryce *et al.,* 2001). Low BCS's in dairy cows can be linked with health such as claw horn lesions with reduced digital thickness (Bicalho *et al.*, 2009) and fertility consequences. Randell *et al.* (2015) found a greater risk of lameness can be associated with BCS's less that 2 and suggest scores of 2.5 or more may be optimal for reducing this risk. Lameness is a significant welfare issue in UK dairy herds particularly in early lactation when it can reduce milk yields and fertility (Kossaibati and Esslemont, 1997) This could effect the financial feasibility of BP system if were shown to lead to increased incidents.

A need to move towards more sustainable food systems driven by anticipated future pressures was one of the motivations behind an experiment to deliver landless milk production, by utilising waste and by-product derived feeds which were generally unsuitable for human consumption. Calls for the increased utilisation of by-products feeds or "ecological leftovers" within dairy systems have arisen because they can attract lower GHG emissions and are able to replace cereals in ruminant rations containing human edible proteins (Garnett, 2009; Roos *et al.*, 2016). Including by-product and waste components within ruminant diets can be commonplace, (e.g. distillers' grains) and has been suggested as a possible method to enhance food supplies and improve food security (Foley *et al*., 2011). A BP system could incur less fixed costs than a LF system as there no fertiliser or associated crop production expenses however high variable costs could diminish profits.

When compared with a LF diet, carbon footprint and land use results from the BP system illustrate possible emission and acreage reductions achieved by replacing forage and fertiliser needs with purchased by-products. Footprint results ranging from 0.83-1.06 kg CO_2e are lower than a reported UK average of 1.25 (DairyCo, 2012) because young stock were not included in this analysis. GHG emissions are one of several environmental externalities arising from dairy production that should be considered when making an environmental assessment. Whole farm environmental studies of dairy production methods within literature illustrate higher or lower impacts from a range of systems depending upon indicators applied (Tuomisto *et al.*, 2012; Ross *et al.*, 2014).

Processing slurry by means of anaerobic digestion (AD) may be one way to adjust a BP system, thereby increasing farm income and producing a more stable and nutrient rich digestate for exportation. Installation of AD is reported to have increased on UK dairy farms, however units can require a considerable long term investment, and it is often not practical, or cost effective to transport manure long distances. Such a landless BP dairy system may be more appropriate in areas of the UK, such as East Anglia, which are dominated by arable production and would typically require fertilisers to be imported, however milk processing facilities would need to be located within a feasible range of farms.

Increased ration costs of a BP TMR combined with lower milk returns suggest this novel diet would not currently appeal to famers. Cows within the Crichton experiment did not refuse the BP TMR, however straw quality was found to be important and chop length was maintained to prevent the animals sorting the ration. Specific transition and dry rations were formulated to ensure adjustments to the BP diet after calving were not detrimental to the cows. Practical matters such as the locale and wider availability of BP feedstuffs are not within the scope of this paper but are appreciated as issues surrounding these products.

Conclusion

Results presented in this comparison of two housed dairy systems demonstrate trade offs occurring between technical, financial and environmental performance indicators stemming from different diets. A novel BP diet was shown to effect the biological performance of the animals which led to trade offs between environmental, health and financial aims. This highlights how strategies aimed at improving one facet of a dairy system could possibly lead to unforeseen feedbacks in other areas. Implementing practises to improve the sustainability of agricultural systems requires a need to understand and address trade-offs and synergies that can occur. This could be achieved via the comparison of indicators under varied scenarios.

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