



## THE EFFECT OF REDUCING THE PROTEIN CONTENT OF THE DIET ON THE PERFORMANCE OF DAIRY COWS



AgriSearch was formed in 1997 to provide a mechanism through which dairy, beef and sheep farmers could have a direct involvement in near market research. Funds contributed to AgriSearch are used to commission research into the improvement and development of sheep, beef and dairy farming and to disseminate and publish the results. Dairy projects are recommended to the AgriSearch Council by a Dairy Advisory Committee.



Agri-Food and Biosciences Institute,  
Largepark, Hillsborough, Co. Down BT26 6DR

#### RESEARCH TEAM

Ryan Law, Fiona Young, Desmond Patterson and Tianhai Yan

Booklet prepared by  
Ryan Law and Conrad Ferris

#### CO-FUNDERS

Department of Agriculture and Rural Development for Northern Ireland



## OVERALL SUMMARY OF PROJECT

- Within Northern Ireland the overall protein content of dairy cow diets is normally approximately 18% (dry matter basis).
- It has been suggested that dairy cow fertility may be improved by reducing the protein content of the diet. Thus a study was undertaken to examine the effect of the protein content of the diet on cow performance and subsequent fertility.
- Dairy cows were offered diets with total protein contents of either 11.5%, 14.5% or 17.5% (dry matter basis), during the first 150 days of lactation.
- While food intake was not affected when the protein content of the diet was reduced from 17.5% to 14.5%, milk yield was reduced by 3.5 litres / cow / day.
- Milk yield was reduced by approximately 10.0 litres / cow / day when a diet containing 11.5% protein was offered. This level of protein was clearly inadequate.
- Cows offered the low protein diet returned to positive energy balance earlier (week 4 post calving) than those offered either the medium (week 6 post calving) or high protein diets (week 12 post calving).
- Although the energy balance of cows offered the medium protein diet (14.5%) was improved, this did not result in an improvement in fertility.
- Reducing the protein content of the diet from 17.5% to 14.5% reduced margin over feed costs by £57 / cow during the first 150 days of lactation. As fertility was not improved, it must be concluded that a protein content of 14.5% is inadequate in terms of cow performance and economic performance.
- Reducing the protein content of the diet reduced the quantity of nitrogen that was excreted in manure, and this has the potential to reduce nitrogen loss to the environment.
- During the second half of the lactation (from day 151 onwards), a diet with a protein content of 14.5% supported the same milk production as a diet containing 17.5% protein, while reducing overall feed costs by £41 / cow.
- Higher yielding cows exhibit standing heat less frequently than lower yielding cows, and as such, secondary signs of heat are important. The two most important secondary signs of heat in the current study were mounting (or attempting to mount) another cow and chin resting.



## BACKGROUND

Dairy cows require protein for growth, milk production, pregnancy, and to support many internal body processes. In addition, dietary protein is a key driver of food intake and milk production. Within Northern Ireland the overall protein content of dairy cow diets is normally approximately 18% (dry matter basis). However, there is currently considerable interest in the use of lower protein diets for dairy cows. The reasons for this are as follows:

**1)** Protein ingredients tend to be the most expensive component of concentrate feeds (e.g. soya bean meal, rape meal). As such, reducing dietary protein levels can reduce the cost of the diet.

**2)** Dietary protein is used inefficiently by dairy cows, with approximately 70% of the protein (nitrogen) consumed ending up in manure. This manure nitrogen can be lost to the environment, and can reduce both water (nitrates) and air (ammonia) quality, and contribute to global warming (nitrous oxide). If cows are offered diets containing less protein, less nitrogen will be excreted in manure, and the risk of nitrogen being lost to the environment will be reduced.

**3)** Offering lower protein diets has been suggested as one option by which to improve cow fertility. The hypothesis is as follows: high yielding dairy cows are unable to consume sufficient food to support their energy requirements in early lactation (negative energy balance), and may lose excessive body condition. A large negative energy balance has been shown to have a detrimental effect on cow fertility. As protein supply is a key driver of milk production, reducing the dietary protein content may provide a tool by which to 'reduce milk yield', while maintaining feed intake. This in theory should improve energy status, and as such, also improve fertility. However, this theory has not yet been tested in practice.



## OBJECTIVES OF THE STUDY

This study was designed to examine the effect of dietary protein level on:

- i) cow performance
- ii) energy balance
- iii) reproductive performance
- iv) efficiency of nitrogen utilisation
- v) the financial impact of offering lower protein diets

## DETAILS OF THE STUDY

- This study involved 90 winter calving Holstein-Friesian dairy cows.
- Cows were allocated to one of three dietary treatments (30 animals per treatment). All cows were offered a complete diet containing 55% concentrate and 45% forage (on a dry matter basis). The forage offered was a mixture of grass silage (27%) and maize silage (18%).
- The concentrates offered within each treatment had different crude protein contents (10.0, 15.0 and 20.0% on a fresh basis).
- Thus on a DM basis, total diet crude protein levels were as follows:
  - i) High (17.5%)
  - ii) Medium (14.5%)
  - iii) Low (11.5%)
- Cows remained on these diets until day 150 of lactation.



## SUMMARY OF RESULTS

### **Intake and milk production**

Reducing the crude protein content of the diet from 17.5% to 14.5% had no significant effect on dry matter intake. However, milk yield was reduced by 3.5 litres / cow / day (Table 1). This loss of performance may be acceptable if fertility is greatly improved.

**Table 1** The effect of dietary protein content on dry matter intake and milk production (mean for first 150 days of lactation)

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Dry matter intake (kg / day)	16.5	18.0	18.6
Milk yield (litres / day)	24.7	30.9	34.4
Butterfat (%)	4.20	3.83	3.81
Protein (%)	3.14	3.23	3.24

Cows offered the low protein diet had a 1.5 kg / day lower dry matter intake than those offered the medium protein diet, while having a 6.2 litre / day lower milk yield. This low protein diet was clearly inadequate.

Milk fat content was highest with cows offered the low protein diet. Milk protein content was not affected by diet.





**Table 2** The effect of the protein content of the diet on cow liveweight and body condition score at day 150 post calving

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Liveweight at day 150 post calving (kg)	545	571	564
Body condition score at day 150 post calving	2.5	2.5	2.4

### Liveweight and body condition score

Cows offered the low protein diet were lighter at day 150 post calving than cows offered the medium and high protein diets. Body condition score at day 150 post calving was not affected by dietary protein level (Table 2). However, energy balance data in Figure 1 suggests that cows on the low protein diet mobilised less body tissue reserves than those on the high protein diet.

### Energy status

One of the key aims of this study was to examine the effect of dietary protein level on the energy status of the cow.

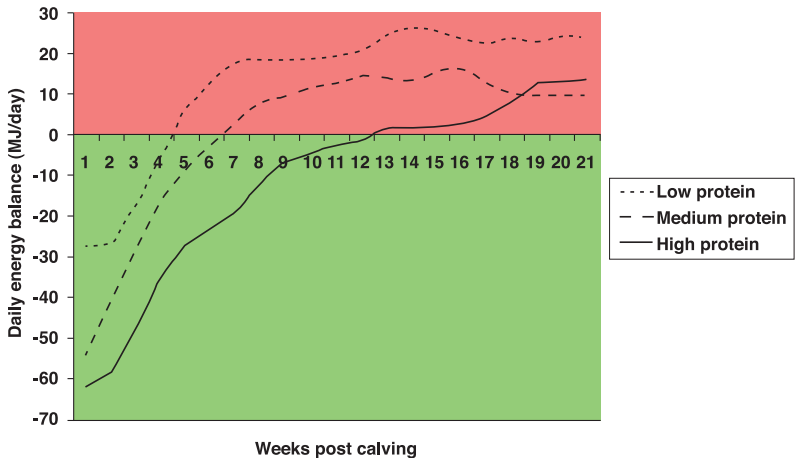
Figure 1 presents the energy status of the cows on each of the three diets during the first 150 days of lactation (until week 21 post calving). The red part of the graph represents negative energy balance (i.e. cows losing body condition), while the green part of the graph represents positive energy balance (i.e. cows gaining body condition).

Cows on all three treatments were in negative energy balance during the first few weeks post calving. However, cows offered the low protein diet returned to positive energy balance earlier (week 4 post calving) than those offered either the medium (week 6 post calving) or high protein diets (week 12 post calving). Thus the theory that offering a low protein diet will improve the energy status of a dairy cow appears to be true.





**Figure 1** Effect of dietary protein content on daily energy balance (Megajoules (MJ) / day)



### Cow fertility

An improvement in fertility might have been expected with cows offered the low protein diets as these cows returned to positive energy balance before cows on either of the medium or high protein diets. However, dietary protein level had no significant effect on any of the fertility measurements (Table 3).







**Table 3** The effect of the protein content of the diet on cow fertility

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Pregnancy to 1st service (%)	35	30	28
Pregnancy to 1st and 2nd service (%)	55	63	52
Pregnancy rate 100 days after start of breeding (%)	83	67	62
Overall pregnancy rate (%)	100	93	87

Nevertheless, there were some trends in the results which suggest that cows offered lower protein diets may have had improved fertility. For example, cows offered the low protein diet tended to have higher pregnancy rates than those offered the medium and high protein diets.

### **Nitrogen utilisation**

As protein contains nitrogen, nitrogen intakes were highest with cows offered the high protein diet (Table 4). Cows offered the high protein diet had the largest nitrogen output in milk, with this simply reflecting their higher milk yields. Nitrogen excreted in manure was lowest with cows offered the low protein diet. This highlights that the use of low protein diets can reduce the risk of nitrogen being lost to the environment.



The last line of Table 4 highlights the overall efficiency with which the nitrogen consumed was used for milk production. With a high protein diet, only 26% of nitrogen consumed was recovered in milk (low efficiency of nitrogen utilisation). The efficiency of nitrogen utilisation increased with the low protein diet, with 31% of the nitrogen consumed recovered in milk.

**Table 4** The effect of the protein content of the diet on the efficiency of nitrogen utilisation

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Nitrogen intake (g / cow / day)	322	445	562
Nitrogen output in milk (g / cow / day)	100	132	144
Nitrogen output in manure (g / cow / day)	227	300	380
% of nitrogen consumed that is recovered in milk	31	30	26



## Methane production

Methane gas is produced when bacteria in the cow's rumen ferment food. As methane is an important 'green house gas' (i.e. contributes to global warming), there is currently considerable interest in options to reduce its production.

Methane production was lowest from cows offered the low protein diet (Table 5), and this was due to the lower intakes of these cows (it is known that cows with higher intakes produce more methane). However, when we examine methane emissions per litre of milk produced, cows offered the high protein diet produced the lowest amount of methane (per litre of milk). This demonstrates that increasing milk production per cow (provided fertility does not decrease) is one strategy by which methane emissions can be controlled.

**Table 5** The effect of the protein content of the diet on methane production

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Methane production (litres methane / cow / day)	513	519	550
Methane production (litres methane / litre milk produced)	25.7	20.9	20.7

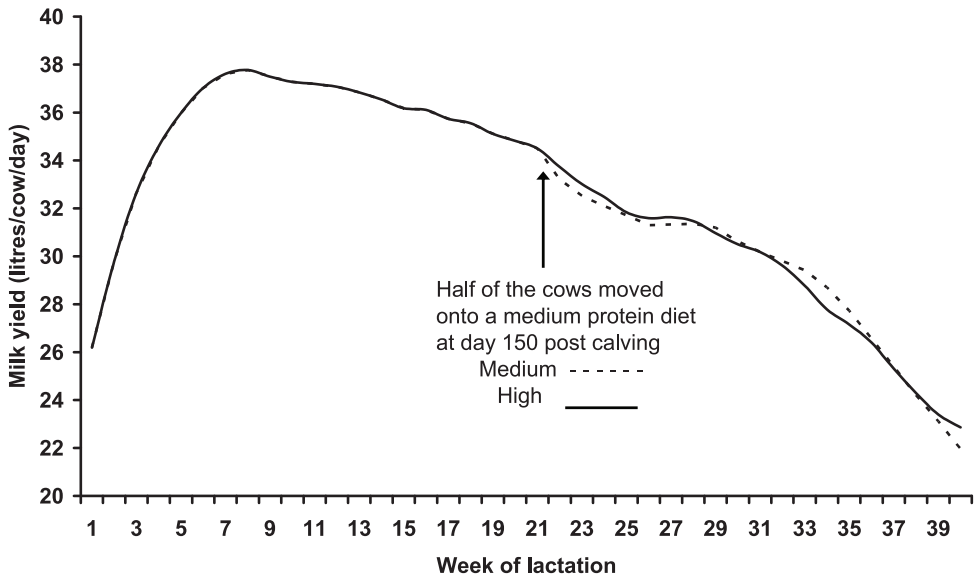


### Can the protein content of the diet be reduced after mid lactation?

The results presented so far relate to the first 150 days of lactation, and these have demonstrated that milk production is substantially reduced when cows are offered a diet with a protein content of 14.5%. However, it is known that the protein requirements of dairy cows decrease in later lactation. To allow this to be examined in more detail, half of the cows on the high protein diet were moved onto a medium protein diet after day 150 of lactation, while the remaining cows continued to be offered the high protein diet.

The results of this part of the experiment clearly demonstrated that after mid lactation (day 150+) there were no detrimental effects on either milk yield (Figure 2) or milk composition when dietary protein content was reduced from 17.5% (high) to 14.5% (medium).

**Figure 2** Effect on milk production of reducing the protein content of the diet, from high (17.5%) to medium (14.5%), at week 22 (day 150) of lactation





### Economics of reducing the protein content of the diet.

The value of milk produced was highest with cows offered the high protein diet (Table 6) due to higher milk yields with this treatment. However, feed costs were also highest with the high protein diet, due in part to the higher cost of high protein meal (in this calculation the high, medium and low protein meals were costed at £174 / t, £159 / t, and £145 / t, respectively).

Margin over feed costs was £57 / cow higher for cows offered the high protein diet, than for cows offered the medium protein diet (over the first 150 days of lactation). As fertility was not significantly improved with the low protein diets, better fertility can not be costed into this calculation. Thus, although the efficiency of nitrogen utilisation was improved with low and medium protein diets, the large reduction in the margin over feed costs with these treatments suggests that these diets are not economically viable.

However, the results presented in Figure 2 indicate that reducing the protein content of the diet to 14.5% after day 150 of lactation had no detrimental effect on cow performance. Based on the above feed costs, this would have resulted in a saving of £41 / cow during the second half of the lactation.

**Table 6** Economic impact of reducing the protein content of the diet during the first 150 days of lactation

	Crude protein content of total diet (DM basis)		
	Low (11.5%)	Medium (14.5%)	High (17.5%)
Value of milk produced until day 150 of lactation (£ / cow) <sup>1</sup>	695	852	948
Feed costs until day 150 of lactation (£ / cow) <sup>2</sup>	340	395	434
Margin over feed costs until day 150 of lactation (£ / cow)	355	457	514

<sup>1</sup> Milk value based on: base milk price, 18 pence / litre; bonus of 0.018 and 0.032 pence / 0.01% increase in milk fat and protein above base (4.0 and 3.18% respectively)

<sup>2</sup> Feed costs: grass silage, £103 / t DM; maize silage, £99 / t DM; high protein meal, £174 / t fresh; medium protein meal, £159 / t fresh; low protein meal, £145 / t fresh



## Heat detection

The cost of replacing cows that are culled due to infertility has been estimated at £18,000 per year for a 100-cow herd. Although reproductive efficiency is affected by many factors, heat detection is a key management factor which influences reproductive success, and one which farmers have a high degree of control over.

Traditionally, 'standing heat' has been recognised as the most useful indicator of heat. However, recent research has demonstrated that the expression of standing heat is greatly reduced in high yielding dairy cows. For example, the expression of standing heat may represent less than 7% of the total heat behaviours expressed. Therefore, the use of 'secondary signs' of heat have become increasingly important.







## Secondary signs of heat

Within this study, standing heat and eight secondary signs of heat (seven oestrous behaviours) were used to assess when cows were on heat. These secondary signs were mucous discharge, enticing other cows (butting, cajoling), restlessness, sniffing the vagina of another cow, chin resting, being mounted but not standing, mounting (or attempting to mount) other cows, and mounting head side of another cow.

Cows were observed for 30 minutes, twice daily (9 am and 9 pm). Following data collection, each behaviour was characterised in terms of reliability, percentage expression and a dependability rank (Table 7). Reliability indicates the percentage of animals that were actually on heat when a given behaviour was expressed, while percentage expression details the percentage of cycles in which a given behaviour was expressed. Dependability rank, which incorporates both reliability and percentage expression, indicates how useful a behaviour is when detecting animals in heat during visual heat observational periods (1 = most dependable, 9 = least dependable).

**Table 7** The dependability of oestrous behavioural activities

Oestrous behaviour	Reliability (%)	Percentage expression	Dependability rank
Mucous vaginal discharge	76	9	9
Entice other cows	87	53	6
Restlessness	79	82	4
Sniffing the vagina of other cow	76	87	3
Chin resting	81	90	2
Mounted but not standing	78	20	8
Mounting (or attempt) other cows	89	83	1
Mounting head side of other cow	95	22	7
Standing immobile on being mounted (standing heat)	96	52	5



The most dependable signs of heat were mounting (or attempting to mount other cows) and chin resting (Table 7). Standing heat was ranked as only the fifth most dependable sign of heat. Although highly reliable when expressed, it is not expressed often enough to make it a dependable indicator of heat. This highlights the importance of observing secondary signs of heat with high yielding dairy cows.



Heat detection rates can be reduced by up to 20% if the duration of each observation period is decreased from 30 to 20 minutes. Each period of heat detection should be a minimum of 30 minutes duration. While current recommendations for heat detection are 2-4 observational periods per day, detection rates will increase with more frequent observation periods each day.

### **Other factors that affect the expression of heat**

While dietary protein content had no effect on the expression of heat, the intensity of heat expression increased when there were more cows 'on heat' simultaneously. An increase in the intensity of heat will allow the accuracy of heat detection to be increased. A close calving pattern and / or a large herd size will increase the likelihood of more animals expressing heat at the same time.

### **Other factors include**

- Adequate space (less heat expression in crowded houses)
- Lameness (cows with sore feet express less intense heats)
- Floor surface (cows less likely to mount on slippery floor surfaces)



## CONCLUSIONS

A protein content of 11.5% was inadequate. While the efficiency of nitrogen utilisation was improved with a protein content of 14.5%, the large reduction in margin over feed costs with this diet indicates that it is not economically viable in practice. However, there is scope to reduce dietary protein levels to 14.5% after mid lactation without a loss in performance, but with the benefits of reduced feed costs.

## ACKNOWLEDGEMENTS

Thanks are due to the technical staff at AFBI, Hillsborough for their assistance in recording and preparing data sets. This study was co-funded by the Department of Agriculture and Rural Development and by AgriSearch.

### **Full details of findings**

Full details of this study, and its findings, can be found in the scientific papers detailed below. These can be accessed at <http://jds.fass.org/>

Law, R.A., Young, F.J., Patterson, D.C., Kilpatrick, D.J., Wylie, A.R.G. and Mayne, C.S. (2009) Effect of dietary protein content on animal production and blood metabolites of dairy cows during lactation. *Journal of Dairy Science*, **92**: 1001-1012.

Law, R.A., Young, F.J., Patterson, D.C., Kilpatrick, D.J., Wylie, A.R.G. and Mayne, C.S. (2009) Effect of dietary protein content on oestrous behaviour of dairy cows during early and mid lactation. *Journal of Dairy Science*, **92**: 1013-1022.

Law, R.A., Young, F.J., Patterson, D.C., Kilpatrick, D.J., Wylie, A.R.G. and Mayne, C.S. (2009) Effect of dietary protein content on the fertility of dairy cows during early and mid lactation. *Journal of Dairy Science*, **92**: 2737-2746.



*DISCLAIMER: The Northern Ireland Agricultural Research and Development Council (AgriSearch) has provided funding for this project but has not conducted the research. AgriSearch shall not in any event be liable for loss, damage or injury suffered directly or indirectly in relation to the report or the research on which it is based.*

# **AGRISEARCH BOOKLETS**

## **1 SHEEP**

The Effects of Genetics of Lowland Cross-Bred Ewes and Terminal Sires on Lamb Output and Carcass Quality

## **2 DAIRY**

A Comparison of Four Grassland-Based Systems of Milk Production for Winter Calving High Genetic Merit Dairy Cows

## **3 DAIRY**

Dairy Herd Fertility - Examination of Effects of Increasing Genetic Merit and other Herd Factors on Reproductive Performance

## **4 SHEEP**

Developing Low Cost 'Natural-Care' Systems of Sheep Production

## **5 BEEF**

An Examination of Factors affecting the Cleanliness of Housed Beef Cattle

## **6 BEEF**

The Effects of Housing System on Performance, Behaviour and Welfare of Beef Cattle

## **7 DAIRY**

Developing Improved Heifer Rearing Systems

## **8 BEEF**

The Influence of Suckler Cow Genetics and Terminal Sire on Performance of the Suckler Herd

## **9 DAIRY/ BEEF**

Reducing Organic Nitrogen Outputs from Dairy Cows and Beef Cattle in Nitrate Vulnerable Zones

## **10 DAIRY**

The Effect of the Type of Dietary Supplement on the Performance of the Grazing Dairy Cow

## **11 DAIRY**

Are International Dairy Sire Genetic Evaluations Relevant to Milk Production Systems in Northern Ireland?

## **12 DAIRY/ BEEF**

Holstein Bull Beef

## **13 DAIRY**

Effective Footbathing of Dairy Cows

## **14 DAIRY**

Effects of Feeding Forage Maize and Whole Crop Silages on the Performance of Dairy Cows Offered Two Qualities of Grass silage

## **15 BEEF**

Maximising Beef Output from the Suckler Herd Through the Production of Heavy Bulls

## **16 DAIRY**

The Effect of Reducing the Protein Content of the Diet on the Performance of Dairy Cows

*For further information or to request a copy of the full scientific report detailing the experimental tests and statistical analysis contact:*

AgriSearch  
97 Moy Road  
Dungannon  
BT71 7DX  
Northern Ireland

T: 028 8778 9770  
F: 028 8778 8200  
W: [www.agrisearch.org](http://www.agrisearch.org)

