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REDUCING PHOSPHORUS LEVELS IN DAIRY COW DIETS

AgriSearch
Farmer Funded Research

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OVERALL SUMMARY OF PROJECT

- Many of our rivers and lakes in Northern Ireland contain high levels of phosphorus (eutrophic). Because of these high phosphorus levels the whole of Northern Ireland has been designated a Nitrates Vulnerable Zone.
- Approximately 60% of phosphorus entering our waterways is of agricultural origin. Most phosphorus is brought onto farms in phosphorus fertilisers and in concentrate feeds.
- Approximately 70% of phosphorus consumed by cows ends up in manure/slurry and is at risk of being washed into watercourses after being spread.
- Reducing phosphorus levels within concentrate feeds is one option by which to reduce the amount of phosphorus in manures. However feeding less phosphorus to dairy cows will be unacceptable if cow performance, health, fertility or welfare are reduced.
- A four year experiment was undertaken in which the quantity of phosphorus fed to dairy cows was reduced by 25% during the winter, and by 16% during the summer.
- Reducing the quantity of phosphorus in the diet had no adverse effect on food intake, milk production or milk composition.
- An analysis of blood and bone samples indicated that there were no long term adverse effects from offering a low phosphorus diet.
- Dietary phosphorus level had no effect on the incidence of either lameness or mastitis.
- Within the current study dietary phosphorus level had no significant effect on cow fertility. Worldwide evidence suggests that unless cows are deficient in phosphorus (ie reduced milk yields and reduced intakes) fertility will not be affected.
- Reducing the phosphorus content of dairy cow diets by 25% resulted in a 45% reduction in phosphorus excreted in manure.
- Lower phosphorus diets are now being offered within Northern Ireland as a result of an agreement across the feed compounding sector. The average dairy cow concentrate in Northern Ireland now has a phosphorus content of 5.7 g/kg.
- Farmers who require a derogation from the Nitrates Directive to allow them to operate at stocking rates greater than 170 kg organic N/ha, must operate with a farm phosphorus surplus of less than 10.0 kg phosphorus/ha/year.
- Offering concentrates with lower phosphorus levels is one option that farmers can adopt to help ensure that their farm phosphorus balance is less than 10.0 kg phosphorus/ha/year.

INTRODUCTION

Where does phosphorus come from?

Phosphorus, an essential nutrient for all plant and animal life, is mined from rock phosphate. However, world reserves of rock phosphorus are limited, and will one day become exhausted. This is one reason why we need to use phosphorus carefully.

Is there a problem with phosphorus in Northern Ireland?

Within Northern Ireland we have very good water quality with respect to nitrates, but many of our rivers and lakes contain high levels of phosphorus. Waters which contain high levels of phosphorus are said to be eutrophic (rich in nutrients).

When phosphorus levels in waters are high, this encourages the growth of algae, and these algae can be toxic to both animals and humans. Removal of algae increases water treatment costs. In addition, high phosphorus levels encourage the growth of water plants, and these can overwhelm rivers and lakes, destroy fisheries, and reduce the recreational value of waterways.

Where does this phosphorus come from?

Phosphorus in our waters comes from many sources, including sewage treatment works, factories, septic tanks and farms. Recent evidence suggests that approximately 60% of the phosphorus in our waters is of agricultural origin.

How does phosphorus from farms get into waterways?

Most phosphorus is brought onto farms in phosphorus fertilisers and in concentrate feeds. One tonne of dairy cow meal can contain over 6.0 kg of phosphorus. However, cows do not utilise phosphorus very efficiently, and up to 70% of phosphorus consumed by cows can end up in manures.

If there is heavy rain after manure is applied, phosphorus within the slurry can be washed into waterways in 'surface runoff'. This is one of the reasons why slurry can no longer be applied during the 'closed periods' (15 October – 31 January). Phosphorus from chemical fertilisers can also be washed into waterways.

In addition, Northern Ireland soils contain high levels of phosphorus, especially in the upper few centimetres. When grazing animals or heavy machinery damage the surface of the soil, soil particles containing phosphorus can be washed into rivers and lakes.

Does the Nitrates Directive apply to phosphorus?

Even though the Nitrates Directive was designed to reduce the loss of nitrates (a form of nitrogen) from agriculture to waterways, it also applies to situations where waters contain high levels of phosphorus. In 2007 the whole of Northern Ireland was declared a Nitrate Vulnerable Zone (NVZ) because of the high phosphorus levels in our waters.

How can we reduced phosphorus losses to waterways?

Two approaches should be adopted. The first involves reducing the amount of phosphorus brought onto the farm (in fertiliser and feeds), while the second involves improving the management of manures and fertilisers, and reducing damage to the soil surface.

The experiment described in this booklet involved the first approach, namely reducing the amount of phosphorus brought onto a farm in dairy cow feed. Within this study, this was achieved by feeding a concentrate with a reduced phosphorus level.

What role does phosphorus have within the dairy cow?

Phosphorus has many functions within a dairy cow, including maintaining bone strength (80% of phosphorus is found in bones), maintaining rumen pH, as a part of cell walls, and in all body processes which require energy. Dairy cows also secrete large quantities of phosphorus in milk each day. Rumen bacteria also require phosphorus to function properly.

How much phosphorus do cows require?

There is still some uncertainty about exactly how much phosphorus dairy cows require. There is also a belief that feeding more phosphorus will improve cow fertility. For these reasons cows are often fed more phosphorus than they actually require.

Can we feed cows less phosphorus?

Feeding less phosphorus to dairy cows will be unacceptable if cow performance, health, fertility and welfare are compromised.

The experiment described below was designed to examine the effect of reducing phosphorus levels in dairy cow diets over a four-year period.

THE EXPERIMENT

Cows on the experiment:

The experiment started with 100 first lactation Holstein-Friesian heifers. All cows were winter calving. A total of 95, 70, 50 and 22 cows completed each of lactations 1-4, respectively. Cows culled during the experiment were not replaced.

Diets offered:

During the winter cows were offered grass silage, maize silage and concentrates (10-12 kg concentrate/cow/day). During the summer most cows grazed and were offered 3-4 kg concentrate/cow/day.

Cows were offered diets containing either 'normal' or 'reduced' levels of phosphorus (Table 1). These different phosphorus levels were obtained by modifying the level of phosphorus in the concentrate part of the diet. The concentrates offered with the 'reduced' phosphorus treatment contained 38% (winter period) and 46% (summer period) less phosphorus than the concentrate offered with the 'normal' phosphorus treatment. With the 'reduced' phosphorus treatment, the phosphorus content of the total diet was 25% (winter period) and 16% (summer period) lower than for the 'normal' phosphorus treatment.

Table 1 Phosphorus content of the concentrates offered, and of the total diet, with the 'normal' and 'reduced' phosphorus treatments (g/kg dry matter)

	Normal phosphorus treatment	Reduced phosphorus treatment	Reduction in phosphorus content (%)
Winter period			
Concentrate phosphorus content	7.1	4.4	38%
Total diet phosphorus content	4.8	3.6	25%
Summer period			
Concentrate phosphorus content	6.7	3.5	46%
Total diet phosphorus content	4.2	3.6	16%

OUTCOMES

The experiment started with 100 first lactation Holstein-Friesian heifers. All cows were winter calving. A total of 95, 70, 50 and 22 cows completed each of lactations 1-4, respectively. Cows culled during the experiment were not replaced.

Intakes:

Rumen bacteria require phosphorus to grow. If the diet of a dairy cow contains insufficient phosphorus, the rumen bacteria may not grow properly and this can result in a reduced food intake. However in this study level of phosphorus in the diet had no effect on food intake, and this suggests that dietary phosphorus levels were adequate (Table 2).

Table 2 Effect of phosphorus level in the diet on dry matter intake during the winter periods in each of lactations 1-4 (kg/cow/day)

	Diet type	
	Normal phosphorus	Reduced phosphorus
Lactation 1	17.6	17.4
Lactation 2	19.9	19.6
Lactation 3	20.8	19.8
Lactation 4	22.9	22.7

Milk production:

Milk production was not affected by level of phosphorus in the diet in this experiment (Table 3). In addition, phosphorus level had no effect on milk composition. However, milk yields have been reduced in other studies when dietary phosphorus levels were less than 3.2 g/kg (dry matter basis).

Table 3 Effect of phosphorus level in the diet on full lactation milk production during each of lactations 1-4 (litres/cow)

	Diet type	
	Normal phosphorus	Reduced phosphorus
Lactation 1	7521	7474
Lactation 2	8241	8419
Lactation 3	9177	9219
Lactation 4	9002	8976

Condition score:
During lactations 3 and 4, cows on the 'reduced' phosphorus diet had a slightly lower condition score than those on the 'normal' phosphorus diet. However, as this was not accompanied by either a lower intake or a lower milk yield, it is unlikely to have been caused by level of phosphorus in the diet.

Blood:
It is generally accepted that blood phosphorus levels do not provide a good indication of the phosphorus status of an cow. Blood phosphorus levels were lower with cows offered the 'reduced' phosphorus diet throughout the experiment, but were not at levels which suggested that cows experienced any long term phosphorus deficiency.

Bones:
Dairy cows have large stores of phosphorus in their bones and they can make use of this bone phosphorus during periods when the level of phosphorus in the diet is inadequate. This will have the effect of reducing the level of phosphorus in bone, and could eventually result in weak bones which are more susceptible to breaking. However, bone samples taken from cows culled during the study indicate that both diets contained sufficient phosphorus to maintain normal bone phosphorus levels.

Cow health:
Dietary phosphorus level had no effect on the incidence of either lameness or mastitis.

Fertility:
Many people believe that there is a link between dietary phosphorus levels and dairy cow fertility. While it is true that cows that are deficient in phosphorus may have poorer fertility, phosphorus deficient cows will also have lower intakes and produce less milk. Within the current study dietary phosphorus level had no significant effect on any of the fertility measurements recorded (Table 4).

Table 4 Effect of phosphorus level in the diet on dairy cow fertility (mean of four lactations)

	Diet type	
	Normal phosphorus	Reduced phosphorus
Cows showing their first heat within 6 weeks of calving	59%	62%
Days to first heat	23	25
Conception to first AI	37%	34%
Conception to first + second AI	67%	60%

However, it is recognised that the number of cows on this experiment was inadequate to really identify if dietary phosphorus level had an effect on cow fertility. This is also a weakness of every experiment undertaken in the past. To overcome this problem researchers in the US examined the combined fertility results from 13 individual experiments (involving a total of 785 cows). When reproductive performance of cows offered Low and High phosphorus diets were compared, level of phosphorus in the diet was found to have no effect on any measurement of fertility performance (Table 5).

Table 5 Average fertility performance across 13 studies involving high and low phosphorus diets (from Satter and Wu, 1999)

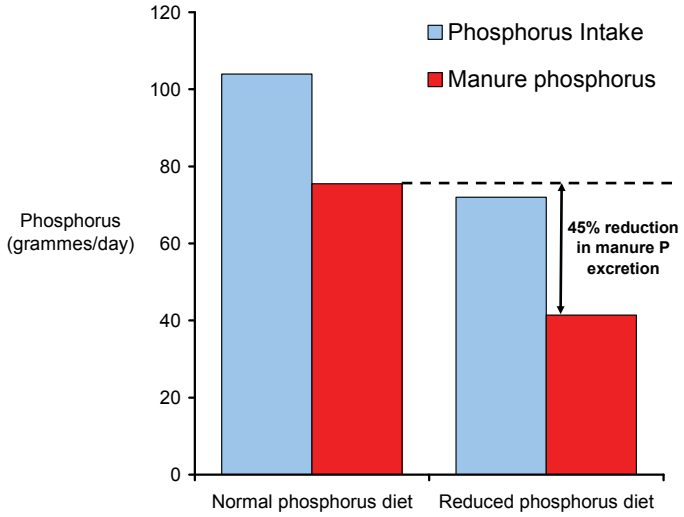
	Diet type	
	Low phosphorus (average 3.6 g/kg DM)	High phosphorus (average 5.0 g/kg DM)
Days to first heat	47	52
Days from calving to pregnancy	103	102
Number of services/conception	2.2	2.0
Pregnancy Rate (%)	92	85

Effect of diet on phosphorus excreted in manure

Reducing the phosphorus content of dairy cow diets will reduce the amount of phosphorus excreted in manure. In the current experiment offering a diet containing a 'reduced' phosphorus level reduced the amount of phosphorus excreted in manure from 75 to 41 g/cow/day, a 45% reduction (Figure 1).

In addition, when cows were fed diets containing lower phosphorus levels, the phosphorus in their manure was found to be less soluble, and thus less likely to be washed into watercourses when slurry was applied to pastures.

Figure 1 Effects of dietary phosphorus content on phosphorus lost in manure



Formulating diets with lower phosphorus levels in practice

- Before this experiment commenced, a survey undertaken by Hillsborough indicated that concentrates being fed to cows in Northern Ireland contained on average 7.1 g phosphorus/kg dry matter (6.2 g fresh basis).

- The results of the current experiment confirms that there is no justification for dairy cow concentrates to contain such high phosphorus levels.

- Recognising this, an agreement was reached within the feed compounding sector within Northern Ireland, that dairy cow concentrates would not contain in excess 6.7 g phosphorus/kg dry matter (5.7 g/kg fresh basis).

- This was a positive move. However, with grass silage based-diets there is potential for this value to be reduced further, perhaps to 4.8–5.5 g/kg (fresh basis).

- However, it can be more expensive to produce concentrates containing lower phosphorus levels. This is largely due to the fact that lower cost ingredients such as maize gluten must be replaced to some extent by more expensive ingredients such as soya-bean meal.

- It is of course the phosphorus content of the total diet (not just the concentrate) which is important. Table 6 summarises the current research evidence concerning total diet phosphorus levels for dairy cows.

- Evidence from this study, and from research undertaken elsewhere, suggests that total diet phosphorus levels can be reduced to 3.6 g phosphorus/kg (dry matter basis) without having a detrimental effect on cow performance.

Table 6 Summary of research evidence concerning total diet phosphorus requirements for dairy cows

Level of phosphorus in the total diet	Research evidence
Greater than 3.8 g/kg DM	Adequate in all studies; overfeeding
3.6 – 3.8 g/kg DM	Adequate in Hillsborough study and virtually all other studies; risk of deficiency very small
3.3 – 3.5 g/kg DM	Inadequate in some studies: some risk of deficiency
2.7 – 3.2 g/kg DM	Inadequate in many studies: high risk of deficiency
2.2 – 2.6 g/kg DM	Inadequate in all studies: very high risk of deficiency

- However, it can be difficult to formulate diets that are very low in phosphorus unless the phosphorus content of the forage part of the diet is known accurately. Unfortunately at present there is no rapid low cost system for determining the phosphorus content of forages.

- As part of this project a number of forage samples were collected from farms around Northern Ireland and analysed for phosphorus content. The average and range of phosphorus contents of these forages are presented in Table 7.

- While most silages have normal phosphorus levels, on some farms very low phosphorus silages were sampled. The lower phosphorus content of maize silages must also be taken into account when formulating diets.

Table 7 The phosphorus content of some common forages sampled on Northern Ireland dairy farms

	Number of samples analysed	Phosphorus content (g/kg DM)	
		Average	Range
Grass silage	36	3.1	1.4-3.9
Maize silage	7	2.4	1.6-3.2
Whole crop cereal silage	7	2.8	2.3-3.1
Grazed grass	24	4.0	2.9-5.2

A 'farm gate' phosphorus balance

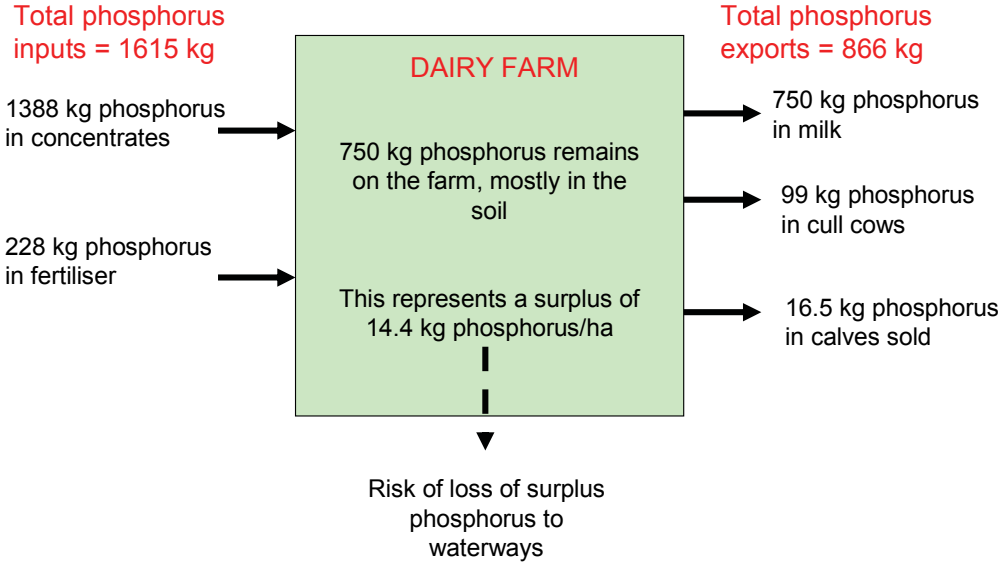
- A 'farm gate' phosphorus balance is the difference between the amount of phosphorus brought onto the farm in one year (for example, in fertiliser and feeds) and the amount of phosphorus removed from the farm in one year (for example, in milk, cull cows and calves).

- Figure 2 provides an example of a phosphorus balance for a 52 hectare farm with 100 dairy cows plus youngstock. In this example the stocking rate is 2.5 cows per hectare, concentrate feed level is 2.2 tonnes per cow per year, annual milk sold is 7500 litres per cow, and the average application of P2O5 is 10.0 kg/ha/year (4.4 kg phosphorus/ha/year).

- In this example, 1615 kg of phosphorus is brought onto the farm in feed and fertiliser, while 866 kg is removed in milk, cull cows and calves sold. Thus 750 kg of phosphorus remain on the farm (mostly in the soil).

- If 750 is divided by the size of the farm (e.g. 52 hectares), the phosphorus surplus is calculated to be 14.4 kg/ha/year. It is this surplus phosphorus which is at risk of being lost to the environment.

Figure 2 Example of a Farm gate phosphorus balance for a typical dairy farm



- Until recently, the average annual phosphorus surplus for a typical Northern Ireland dairy farm was approximately 18 kg phosphorus per ha, while a few individual farms had an annual phosphorus surplus in excess of 30 kg phosphorus per ha!

- Within Northern Ireland farmers who require a 'derogation' from the Nitrates Directive to allow them to operate at a stocking rate of more than 170 kg organic nitrogen/ha, are required to have an annual farm-gate phosphorus balance of less than 10.0 kg/ha.

- Derogated farms must submit a 'Fertilisation Account' to NIEA which demonstrates that the farm phosphorus surplus does not exceed the 10.0 kg per hectare limit.

- The Nitrates Directive Derogation Guidance Booklet recently produced by DARD and the Northern Ireland Environment Agency (NIEA) highlights how to determine the phosphorus balance for your farm. In addition, a phosphorus balance calculator is available on the RuralNI website (www.ruralni.gov.uk).

Options for reducing farm gate phosphorus balance

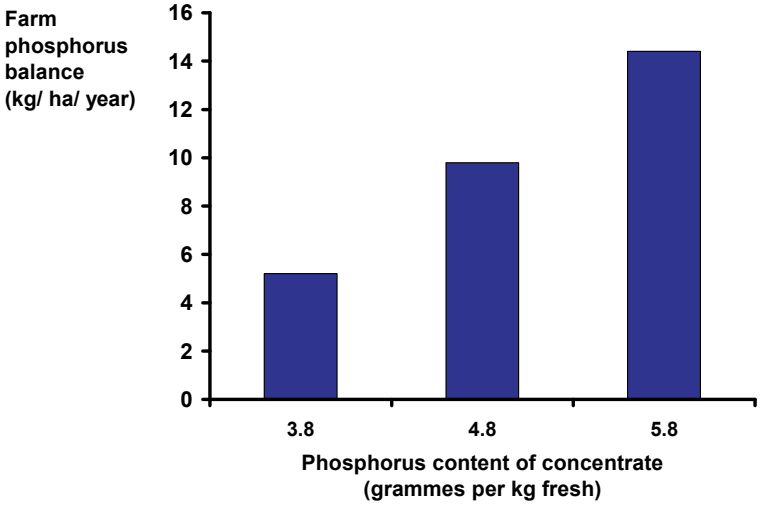
The phosphorus balance on your farm will be influenced by a wide range of factors, including stocking rate, concentrate feed levels and milk production per cow. Some options by which the phosphorus surplus on your farm can be reduced include:

- *Feed a lower phosphorus concentrate:* purchasing a concentrate with a lower phosphorus level, as described in this report, may be part of the solution. The effect of reducing the level of phosphorus in the concentrate on overall farm phosphorus balance is illustrated in Figure 3 (for the farm highlighted in Figure 2).

  In this example, when the phosphorus content of the concentrate was reduced from 5.8 g to 3.8 g/kg fresh basis, the annual phosphorus balance for the farm was reduced from 14.4 kg/ha to 5.8 kg/ha. This example clearly highlights the potential of offering concentrates containing reduced phosphorus levels, as a means of reducing the phosphorus surplus on a farm.

  However, it is also important to take account of the level of phosphorus in the forage component of the diet, and consequently this approach should be discussed with your adviser/nutritionist.

Figure 3 Effect of the phosphorus content of the concentrate on farm phosphorus balance



- *Feed less concentrates:* CAFRE Benchmarking indicates that dairy cow concentrate feed levels have increased from approximately 1.1 to 2.1 tonnes/cow per year during the last decade, while milk yields per cow have increased by approximately 1000 litres. It would appear that dairy cows on many farms are being over-fed concentrates, and this will reduce profitability.

  In general, if concentrate feed levels are less than 2.0 tonnes/cow/year, an annual farm phosphorus balance of less than 10.0 kg/ha should be relatively easily achieved (provided little phosphorus fertiliser is used). However, this becomes more difficult on farms feeding in excess of 2.5-3.0 tonnes concentrate/cow/year, especially if fertiliser containing phosphorus is also purchased.

- *Substitute purchased concentrates with home grown cereals:* This will reduce the quantity of phosphorus imported onto the farm in concentrates.

- *Purchase less phosphorus fertiliser:* Within Northern Ireland chemical phosphorus fertiliser can only be applied if a soil analysis shows a phosphorus requirement. Many fields in Northern Ireland have a high soil phosphorus index, and have no additional requirement for fertiliser phosphorus.

- *Export slurry:* when appropriate, slurry can be exported to other farms, provided appropriate records are kept.

- *Reduce stocking rates:* either by increasing land area, or reducing stock numbers. This may be the only viable option on some highly stocked farms.

Other strategies to reduce phosphorus loss to waterways

- *Careful management of manures and fertilisers:* Follow the regulations set out within the Nitrates Action Programme for Northern Ireland. These are designed to minimise the risk of nutrients from manures and fertilisers entering water courses.

- *Improved slurry spreading techniques:* AFBI research is currently examining the impact of slurry spreading technique on phosphorus losses. Early results suggest that phosphorus losses are reduced when slurry is spread using a trailing shoe system.

- *Minimise damage to soil.* AFBI research has demonstrated that heavy trampling of swards by cows in early spring can lead to increased phosphorus loss.

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

17 DAIRY
Comparisons of Dairy Cow Management Strategies which Differ in Labour Inputs

18 DAIRY
Reducing Phosphorus Levels in Dairy Cow Diets

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

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