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**An evaluation of major nutrients in dairy  
pasture in New Zealand and their effects on milk  
production and herd reproductive performance**

**A thesis presented in partial fulfilment of the requirements for  
the degree of Doctor of Philosophy in Plant Science  
at Massey University, Palmerston North**

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## ABSTRACT

This thesis presents the results of seven experiments or trials between August 1990 and November 1994 designed to study the causes and effects of the variation in nutrient content within dairy pasture in New Zealand and their impact on dairy cow lactation and reproductive performance.

The work includes the results of two observational studies; a survey of seasonal variation in dairy pasture nutrients on four dairy farms; two controlled field trials of supplementation of pasture fed cows in seven commercial dairy herds (involving 1650 cows); an experiment recording changes in pasture nutrients with grazing, maturity and soil phosphate levels; and a replicated split plot trial measuring changes in pasture nutrients after nitrogen (N) application. Trials or experiments involved aspects of agronomy and pasture management, herd reproductive performance and dairy cow nutrition.

A common theme of the work was examination of factors affecting the high crude protein levels present in the diets of dairy cows consuming fresh ryegrass/white clover pasture, measurement of this and testing of some practices that may affect the productive penalties caused by these high protein levels.

Section 1 of the thesis deals with the initial observations (Chapter 1) and a survey of pasture nutrient changes through all seasons on four dairy farms (Chapter 2).

The first chapter describes the initial observational studies over two springs (1990 and 1991) in nine commercial dairy herds and additional survey information from 35 herds (1991). There was a strong negative relationship between urea levels in blood (or milk) and milk production in three separate datasets using principal component analysis (PCA). Milk urea levels related closely to pasture protein levels and especially protein/soluble carbohydrate ratios in pasture. Herd reproductive performance was also worse in the herds with higher urea levels. For example, the four herds observed in

1990 averaged 23.62, 24.09, 20.91 and 21.88% for pasture crude protein; 7.38, 8.20, 5.85 and 6.20 mmol/l for serum urea; and 0.74, 0.75, 0.94 and 0.91 kg milkfat/cow/day respectively over the 17 week period. “Empty” (non-pregnant) cow percentages for the herds were 10.6%, 4.2%, 1.8% and 3.1% respectively. Tentative conclusions were made on the basis of these findings relating especially to the potential negative effects of excess dietary crude protein in pasture on milk production and on herd reproductive performance. These conclusions were then explored in more depth and reported in subsequent chapters.

Seasonal changes in pasture nutrients on dairy farms were measured by analysing pasture collected over two years from four dairy farms of varying soil type and climate (Chapter 2). Two of the farms were at Massey University and two in the Waikato district. All farms were of above average productivity for their district. Samples were collected every two weeks from each farm and represented pasture about to be consumed by cows on these farms. These were analysed for major nutrients or analytes (crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), soluble carbohydrates (SOLCHO), pectin, digestibility (DOMD), potassium, calcium, phosphorus, and magnesium) using near infra red spectrometry (NIRS). Highest pasture CP, DOMD, and SOLCHO levels were found in spring and autumn (ranging from 23.6-25.8%, 75.4-78.1% and 9-12% DM respectively) with lowest ADF, NDF and pectin levels (ranging from 27-28%, 36-38% and 1.8% respectively). The converse applied to the summer period with 20-22% CP, 70-71% DOMD, 8-10% SOLCHO, and 29-31% ADF, 42-45% NDF and 2-2.5% pectin. Calcium and magnesium levels were highest in summer (0.8% and 0.2% respectively compared to 0.65% and 0.19% respectively), and potassium higher in spring and winter (3.2%). The potential consequences for milk production from dairy cows calving seasonally are discussed, with particular reference to the imbalance in the rumen between rumen degraded protein and fermentable carbohydrates. Especially notable were the seasonal differences in protein levels and the changes in the type of carbohydrate available in late spring/summer. Soluble carbohydrate decreased, and fibre expressed as NDF and ADF increased in late spring and summer.

Section 2 of the thesis deals with supplementation trials on 6 commercial dairy herds (Chapter 3) and another supplementation trial on a 7th herd involving maize silage and concentrates (Chapter 4).

Controlled supplementation trials on six commercial dairy herds (total 1380 cows) were carried out in spring 1992 to examine the reproductive and productive effects of supplementing pasture-fed cows with carbohydrates (either soluble carbohydrate or starch). Herds were split into treated and control groups on each farm to remove individual farm factors from the experiment and relatively low levels of either molasses (3 herds, 700 mls molasses/cow/day) or concentrate (3 herds, 1.3 kg concentrate/cow/day) were fed for an extended period in spring (approximately 90 days, from 1 September to 25 November). Significant milk production and reproductive effects were measured when results were pooled for all herds. Immediate responses were approximately 0.5 litres of milk per kg of supplement on average, but the main milk production response was observed later in the experiment (October and November) and was higher in better fed herds and those in better body condition. No effect was found on non-return rate or submission rate, but empty cow rates at the end of the mating season in the supplemented group were half those of the control groups (2.7% vs 5%). These results may indicate considerable productive and reproductive advantage in supporting pasture fed cows through October/November with appropriate supplement when ryegrass is in the reproductive phase, and has reduced digestibility which is likely to limit intake of ME. Improving diet quality or ME concentration at this stage may help reduce the monthly decline from peak lactation which typically occurs at this time in most districts in New Zealand.

Chapter 4 describes a controlled supplementation trial which was carried out in spring 1993 on a 240 cow commercial dairy herd where the diet was formulated according to recommended nutrient levels for high production (NRC, 1989). The diet was improved in content of "bypass" protein, soluble carbohydrate, lipid and minerals. The base diet for control and treated groups was pasture and maize silage. Both control and treated herds were offered the same amount of metabolisable energy (ME) - ie. the diets were iso-energetic. Improved milk production (2 litres milk) and reproduction (2.7% empty vs 6%) occurred in response to the addition of the balancing concentrate in the treated

group. There was a large carryover effect when the concentrate feeding ceased and the sole diet was pasture. Pasture dry matter assessment indicated the supplemented cows continued to consume more dry matter than control cows. The immediate response to supplementation was 1.25 litres/kg DM of supplement, and with the carryover response added exceeded 2.5 litres/kg DM of supplement. The immediate response improved after supplementation had continued for 2-3 weeks. This trial did not show substitution for pasture, but the converse. Improving the balance of dietary nutrients in pasture did improve performance.

Section 3 of the thesis deals with aspects of grazing management, agronomy and the effects of application of nitrogen to pasture on the nutrients within pasture (Chapters 5 and 6).

Variation in pasture nutrients from week to week was evident in the seasonal study presented in Chapter 2. More information regarding changes in pasture nutrients after grazing and as pasture matures was sought because this was considered a likely source of variation in productivity. In Chapter 5 nutrient levels in pasture were determined after grazing or in pasture left ungrazed by sampling every five days during spring from five sites located on two dairy farms. Sites were either grazed as part of normal rotation (3 sites) on the farm or were caged (2 sites) to prevent grazing. Conclusions from this study were limited by a lack of replication, but nevertheless highlighted reduced CP with maturity, increased NDF with maturity and immediately after grazing, reduced SOLCHO just after grazing and reduced digestibility with the advancement of spring into October. Pectin and calcium levels increased as spring advanced. The results were consistent with literature on the subject.

The effects of the level of nitrogen fertiliser and the timing of application in spring on pasture nutrient composition were examined in the final experiment reported in Chapter 6. Nitrogen was identified from the literature as one of the main external influences likely to affect pasture protein levels. Nitrogen was applied as urea to small (2 m<sup>2</sup>) plots at 0, 20, 40 and 80 kg N/ha and at varying times (15 August, 31 August and 14 September) in late winter/early spring to dairy pasture at the Massey University Dairy Research Unit. The trial was a replicated split plot design with levels of N randomised

within starting dates. Significantly reduced ADF and NDF levels, reduced SOLCHO, reduced dry matter %, and increased CP levels occurred after N application. Higher N rates produced greater changes. Application of N earlier in winter resulted in greater effects on ADF (2% difference vs 6%), NDF (2% difference vs 6%) and CP (5% vs 7%) but lesser effects on SOLCHO (1.5% difference vs 0.5%) and these lasted longer in wintery conditions. Effects on SOLCHO were more marked later in the experiment. Brix values (a refractometer measurement of juice squeezed from the herbage sample) were also examined as part of this study to evaluate their usefulness as a rapid measure of SOLCHO concentration; results were inconclusive. The consequences of the effects of N on pasture for dairy cows are discussed and possible dietary or management improvements to minimise the consequences are suggested. The increased protein and reduced fermentable carbohydrate (reduced SOLCHO and reduced ADF or NDF) mean that poorer rumen fermentation could occur after N application, with lower amounts of bacterial tissue presented to the small intestine from ruminal fluid.

A final summarising chapter (Chapter 7) combines the conclusions from the various studies, indicates the need for further information and discusses how this might be obtained. Studies presented in this thesis have not conclusively shown that high CP in pasture has damaging effects on productivity, but have indicated strong associations and various factors influencing pasture CP and also other pasture nutrients.

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## FOREWORD

This thesis began with on-farm observations made over a period of 16 years as a practising veterinarian on the frequency of dairy herd reproductive problems in seasonally calving dairy herds in the Waikato district. In adverse springs (very wet or overcast weather for prolonged periods in August/September/October) the incidence of anoestrus, poor conception and non-pregnant cows increased. Milk productivity was also correlated with herd reproductive performance, with better performance in high producing herds. Assessment of pasture suggested that poor performance did not necessarily relate to the quantity of dry matter available to the cows (as was often assumed), and the hypothesis formed was that changes in nutrients within pasture were at least in part responsible for differences in herd reproductive performance, and that these changes would reflect in selected blood parameters in cows within these herds.

The objectives of the studies reported in this thesis were a) to test these hypotheses in the context of commercial dairy herds, b) to evaluate the impact of alternative management practices on the nutrient balance of grazed pasture, and c) to assess the value of alternative supplementary feeding strategies in overcoming the limitations of grazed herbage as a source of nutrients for lactating dairy cows.

Studies began in 1990 when four herds were selected for their likely herd reproductive performance and herd milk production performance based on previous client records in the veterinary practice. These herds were monitored in detail for reproductive performance, milk production, changes in selected blood parameters, and the nutrients within the pasture consumed. Interactions between the measured data were then examined and interpreted. The observational study was repeated in 1991 in order to include dry matter intake and bulk vat milk urea measurements. The observational studies provided strong evidence of associations between weather conditions, pasture nutrients, blood parameters, herd reproductive performance and milk production.

The observational studies led to a survey establishing normal seasonal variation in pasture on dairy farms, controlled field trials with supplements designed to address

nutrient deficiencies identified in pasture, and studies designed to identify factors affecting nutrient levels in pasture like fertiliser application of phosphate and nitrogen, and also the effects of grazing and maturity on pasture nutrients.

The thesis consists of 3 sections. The first section includes the results of the initial observational studies and the survey of seasonal variation in pasture nutrients from four dairy farms. These serve as the basis from which the other work developed, although chronologically the survey of seasonal variation occurred after some of the other work was already complete. It was realised that this fundamental survey information (Chapter 2) was not available in the literature. The second section presents the results of controlled supplementation experiments in commercial dairy herds in spring where the pasture diet was supplemented with nutrients designed to correct imbalances in pasture identified in Section 1 when compared to recommendations for high producing cows. The third section presents the results of two experiments designed to clarify aspects of pasture management and fertiliser use likely to influence pasture nutrient status. In particular, the effect of grazing, pasture maturity, soil phosphate status, nitrogen (N) application to pasture and the timing of N application in the winter spring period were examined. A concluding chapter links the work in the 3 sections and suggests further studies to extend the results presented.

The subject matter of the thesis is varied, and therefore the normal thesis convention of an introductory literature review has not been followed. Instead, each chapter starts with an extended introduction in which the appropriate literature is cited. Chapter 7 then links the findings in the various chapters and makes conclusions. Physical assistance with the studies is acknowledged at the end of each chapter.

Commercial dairy farms were selected for most of the trial work in an attempt to keep the work relevant to practical circumstances encountered on farms. This made for difficulty in working with standard statistical design, but provided the opportunity to work with substantial numbers of cows (eg 1400 cows for the carbohydrate supplementation trial in Chapter 3) and a more powerful basis for ensuring effects on reproductive performance.

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