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USING THE CORNELL NET CARBOHYDRATE AND PROTEIN SYSTEM TO PREDICT RUMINAL PH IN DAIRY COWS GRAZING HIGH QUALITY PASTURE

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SUMMARY
Predicting milk production is complex due to interactions between the requirement for nutrients by the cow, the characteristics of different feeds and the contributions from body reserves towards the animal's requirements. Grazing introduces more complexity because of the variation in the characteristics of the forage, variation in nutrient intake between cows, diurnal patterns of eating, and further energy demands due to the effort of grazing. Ruminal pH is a critical determinant of metabolisable energy supply because of effects on the growth of different groups of microorganisms in the rumen. Our objective was to use the Cornell Net Carbohydrate and Protein System model to determine whether it was possible to predict ruminal pH for a range of pasture-based diets, based on inputs of nutrient intake, milk composition, liveweight and body condition. There was no (P>0.05) relationship between observed and predicted ruminal pH. The average daily ruminal pH for observed and predicted pH were similar and the mean bias was small and not different to zero. However, when the residuals were regressed against the predicted pH, a positive (P<0.05) systematic bias was demonstrated with pH over-predicted at low pH (5.7 to 6.0) and under-predicted at higher pH (6.1 to 6.2).

Keywords: CNCPS model, grazing dairy cows, pasture intake, nutrient intake, observed and predicted pH

INTRODUCTION
A number of mechanistic models have been developed to predict sufficiency of nutrient supply relative to cow requirements, with the Cornell Net Carbohydrate and Protein System (CNCPS) most widely used as a steady state model for cows consuming total mixed rations (NRC 2001). However, the CNCPS has had limited evaluation with pasture diets. The CNCPS is based on mechanistic and empirical equations that predict the metabolisable energy (ME) and metabolisable protein requirements of cattle, and the supply of nutrients from the diet to meet these requirements (Russell *et al.* 1992; Sniffen *et al.* 1992; O'Connor *et al.* 1993; Pitt *et al.* 1996; Fox *et al.* 1999). Supplies of nutrients are determined by the rate and extent of digestion of the carbohydrate and protein fractions, which are used to calculate the amount of structural carbohydrate and non-structural carbohydrate available for each of 2 microbial pools (Sniffen *et al.* 1992). In pasture fed cows, Kolver *et al.* (1998) showed that the CNCPS had difficulties predicting ruminal pH in a pH range of 6.0 to 6.2, despite good agreement with ME supply. Simulations with pastures with characteristics that lead to low ruminal pH are limited.

Pastures that are highly digestible often result in low ruminal pH (<6.0), which reduces ME supply by inhibiting the growth of microorganisms in the rumen (Pitt *et al.* 1996). The CNCPS was used to determine whether predicted ruminal pH accurately reflected the observed responses. Our objective was to determine the reliability of the CNCPS model for predicting ruminal pH for a range of pasture-based diets.

MATERIALS AND METHODS
Two recent data sets from research with grazing dairy cows (Wales *et al.* 2001; Dalley *et al.* 2004) were used to test the ability of the CNCPS (version 5.0.33) to accurately predict ruminal fluid pH. These experiments were conducted with dairy cows grazing highly digestible perennial ryegrass (*Lolium perenne* L.) pasture, when offered either a high or restricted allowance of pasture, with or without supplements of grain or hay.

Cows in the experiment reported by Wales *et al.* (2001) were offered pasture at allowances (measured to ground level) of 20 or 40 kg DM/cow/day. Additional cows offered the low allowance were also offered supplements of pasture hay as a cube or pellet (2.5 kg DM/day), barley-based cereal grain as a pellet (5.0 kg DM/day) or cereal grain plus pasture hay (7.5 kg DM/day) as a cube (1.97:1 DM basis) or pellet (1.75:1 DM basis). The 7 treatments were replicated 3 times, and 63 cows were used (9 cows per treatment). Cows from high and low allowance treatments consumed herbage with a ME concentration of 12.2 MJ/kg DM, neutral detergent fibre (NDF) concentrations of 43.7 and 46.0% DM, and a crude protein (CP) concentration and 21.5% DM. The ME and NDF concentration of the cereal grain and hay pellet and hay cube were 12.7, 7.7 and 7.4 MJ ME/kg DM and 18.2, 65.8 and 67.4% DM, respectively. The mean daily ruminal pH, based on six 4-hourly samples on 2 occasions, ranged from 5.76 to 6.01 between treatments.

Cows in the experiment reported by Dalley *et al.* (2004) were offered pasture at an allowance (measured to ground level) of 22 kg DM/cow/day. Treatments were pasture only, pasture plus cereal grain as a pellet (6.0 kg DM/day) or cereal grain plus sodium bicarbonate (6.0 kg DMgrain/day with 300 g buffer/day), and grain plus low quality hay pellets (8.2 kg DM/day) or grain plus high quality hay pellets (9.9 kg DM/day). The cereal grain pellet and the cereal grain plus low quality hay pellet were from the same source as that described by Wales *et al.* (2001). The 5 treatments were replicated 3 times, and 60 cows were used (12 cows/treatment). Cows consumed pasture with a ME concentration of 12.3 MJ/kg DM, and NDF and CP concentrations of 42.6 and 24.6% DM. The ME and NDF concentration of the cereal grain, the cereal grain plus low quality hay pellet and the cereal grain plus high quality hay pellet were 11.6, 10.4 and 10.1 MJ ME/kg DM, and 20.2, 32.2 and 32.8% DM, respectively. The mean daily ruminal pH, based on twelve 2-hourly samples on 2 occasions, ranged from 6.1 to 6.2 between treatments.

Table 1 describes the inputs for simulations based on CNCPS feed library feeds with similar NDF and CP characteristics.

Table 1. Estimated inputs based on characteristics described in the Cornell Net Carbohydrate and Protein System feed library.

	Pasture	Grain	Hay pellet	Hay cube
Physically effectiveness factor (% NDF)	30	30	35	40
Starch (% NFC)	48	90	42	42
Fat (% DM)	6.9	2.2	2.0	2.0
Ash (% DM)	10.7	2.4	7.2	7.2
CHO-A (%/hour)[A]	253	300	250	250
CHO-B1 (%/hour)[B]	21.5	30.0	30.0	30
CHO-B2 (%/hour)[C]	16.0	5.0	3.0	3.0

[A] Degradation rate of sugars
[B] Degradation rate of starch and pectin
[C] Degradation rate of available NDF

Two statistical tests were used to evaluate the reliability of the CNCPS as a tool for predicting ruminal pH in pasture-fed dairy cows. Methodologies were based on those described by Chaves *et al.* (2003). The first approach was to evaluate the outputs from CNCPS by linear regression, regressing observed values reported in the scientific papers with predicted responses. The second approach used methods of deviation, based on the root mean square prediction error (RMSPE), where RMSPE = $\sqrt{[\sum (\text{predicted-observed})^2/\text{number of observations}]}$ (Kohn *et al.* 1998). The RMSPE is the square root of the estimate of variance of actual values about the predicted values, and can be partitioned into the mean bias, where mean bias = $\sum$(predicted – observed)/number of observations, and residual error, where residual error = $\sqrt{[\sum \text{RMSPE}^2 - (\text{mean bias})^2]}$. The mean bias describes the average inaccuracy of the model predictions across all data, while the residual error is the remaining error after accounting for the mean bias. Finally, regressions of residuals, defined as the predicted values minus the observed values, were constructed to test the relative size of any bias changes over the range of the predicted values. Significant residual regressions indicate systematic bias in the predictions.

RESULTS AND DISCUSSION

Evaluation of the precision of predicted outputs helps to establish how useful the model is for providing nutritional advice and identifying areas for further research, based on where the model fails to accurately reflect those data observed in experiments. The following discussion relies on the assumption that the observed published data truly reflects responses to treatments, but it is acknowledged that the experimental data will have errors associated with them.

There was no (P>0.05) relationship between the observed and predicted ruminal pH (Figure 1) despite the influence of NDF and physical effectiveness factor (pef) on both the pH and ME concentration of the diet. The ability of the model to predict ruminal pH was poor, with pH over-predicted at low pH (5.7 to 6.0) and under-predicted at higher pH (6.1 to 6.2).

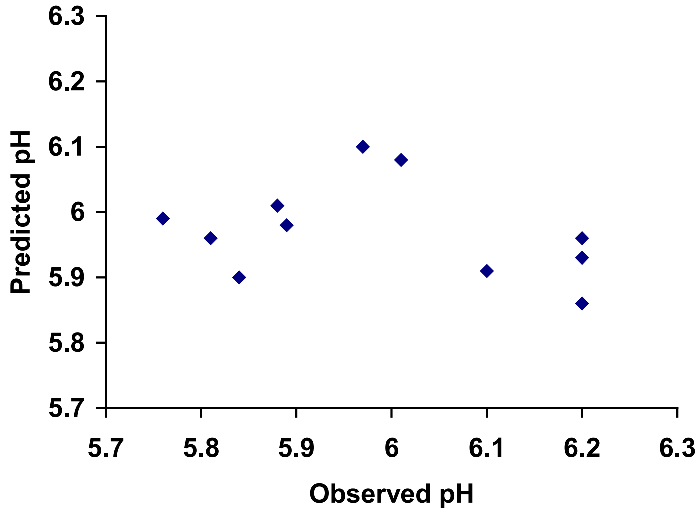

Figure 1. Observed daily ruminal fluid pH versus ruminal pH predicted by the Cornell Net Carbohydrate and Protein System.

The average daily ruminal pH for observed and predicted pH were similar at 5.99 and 5.97 respectively, and the mean bias was small (-0.016 pH units), and not different to zero. The RMSPE was 0.193 pH units. However, when the residuals were regressed against the predicted pH, a significant (P<0.05) positive systematic bias was demonstrated (Figure 2). This is consistent with the findings of Kolver *et al.* (1998) and Kolver and de Veth (2002), who reported model over-prediction when pH was lower than 6.2.

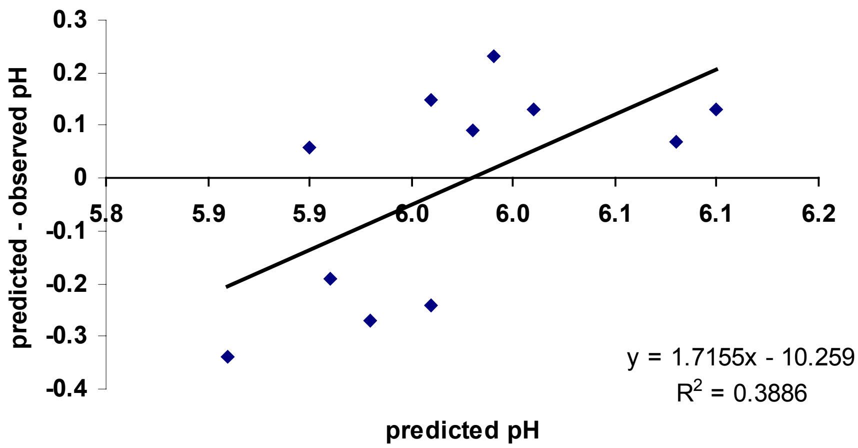

Figure 2. Predicted ruminal pH minus observed pH versus predicted ruminal pH.

At an observed ruminal pH of 5.75, the CNCPS over-estimated pH by about 0.2 pH units. However, manipulation of the CNCPS to match the pH observed in grazing cows required changes to the effective NDF (eNDF), where eNDF = pef*NDF %, which led to a severe negative impact on the supply of ME. The pasture-only examples had eNDF dietary concentrations that were below a threshold of 20% eNDF. Below 20% eNDF, microbial yield is reduced by 2.5% units for each further percentage drop in eNDF, due to the negative effects of low pH on growth of cellulolytic microbes. The over-estimate by the CNCPS of 0.2 pH unit represents an increase of about 2% eNDF units, and is equivalent to an increase in microbial yield of 5% units. Increasing the degradation rate of the digestible NDF fraction (CHO-B2 carbohydrate), and reducing the eNDF content in order to match predicted and observed pH, resulted in an unacceptably low microbial yield and NDF digestibility, and ME supply. Pitt *et al.* (1996) acknowledged that the pH model based on eNDF was not good, but it was better than 1 based on volatile fatty acids (VFA).

There are other indications that the threshold of 6.2 may not be applicable for cows grazing pasture-based diets. The reasons are linked to the idea that low pH is caused by lactate, due to the fermentation of starch, and low pH associated with grain diets has been shown to reduce fibre digestibility (Slyter 1976). However, fermentation of pasture results in formation of VFA that lead to a reduction in pH, but 1 that may not have the same negative affect on microbes as that observed with a lactate-type fermentation. Also, ruminal pH in grazing cows varies markedly during the day due to the pattern of eating, and may not adversely affect the digestion of the structural carbohydrates because pH is sufficiently high for part of the day for adequate fibre digestion (de Veth and Kolver 2001).

A final issue that we have not considered is the potential for compensation by enhanced post ruminal digestion. Although ME supply and pH in the rumen are associated, significant amounts of energy are derived post ruminally, and the higher observed ME supply may just reflect this.

CONCLUSION

Our results confirm previous research with pastures and total mixed rations and suggest there are limitations with the equations used in the CNCPS to determine ruminal pH. The current simulation has shown that highly digestible pastures are poorly modelled and highlights problems associated with modelling situations that are outside the data set range on which the model was built.

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