Evaluation of the values for ruminant nitrogen retention used in the National Greenhouse Gas Inventory

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Prepared for the Ministry of Primary Industries
by MD Bown, BC Thomson and PD Muir
On-Farm Research Ltd, PO Box 1142, Hastings
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Executive Summary

The values for ruminant nitrogen (N) retention used by the National Greenhouse Gas Inventory and described by Pickering (2011) to predict nitrous oxide (N_2O) emissions of farmed ruminants were reviewed and assessed for their accuracy and relevance to current New Zealand conditions.

The review evaluated the values used for N retained in liveweight gain and milk production in dairy and beef cattle, sheep and deer, and for sheep's wool and deer velvet antler.

1. Nitrogen retained in liveweight gain (N_{lwg})

The current model (Pickering 2011) does not adequately define the nitrogen content in body tissue (N_{bt}) and the definition varies between species. The information required (N_{bt}) is the *nitrogen content of live weight gain* (%N or gN/kg LWG) for each month.

a) **N_{bt} for cattle.** The current value of 3.26% N is higher than values reported in the literature.

   This review recommends that the model adopts a revised value of 2.13% N per kg of liveweight gain for both dairy and beef cattle. At present there is insufficient data to justify application of different values for N_{bt} in dairy and beef cattle.

b) **N_{bt} for sheep.** The current model value for N_{bt} of 2.60% N is higher than values in the literature.

   This review recommends that the model adopts a revised value of 2.04% N per kg of liveweight gain.

   With both sheep and cattle, there is evidence that the precision of the model could be improved by adopting an approach where nitrogen content of gain varies with liveweight and rate of gain (which is biologically relevant in relation to breed type, mature size and sex) if data is available.

   This review recommends that an improved method of predicting N_{bt} is developed and validated based on the equations of ARC (1980), AFRC (1993) and CSIRO (2007) which have the potential to account for effects of breed, age, sex, mature size and growth rate on nitrogen composition of liveweight gain in sheep and cattle.

c) **N_{bt} for deer.** The current model value for N_{bt} of 3.71% N is not adequately defined and is higher than values available from very limited data in the literature.

   This review recommends that until more reliable data are available the value for N_{bt} of 3.22% N, which is based on experimental data, is adopted.

2. Nitrogen retained in milk (N_{rm})

a) **N_{rm} for dairy cattle.** The current model value for milk protein concentration (P) of 3.77% CP is based on average herd milk yield (litres) and protein yield (kg) data from New Zealand Dairy Statistics for the season 2010/11. It has not been corrected for milk density (1 litre milk = 1.03kg). After correction this value should be 3.66% CP (36.6gCP/kg milk).

The New Zealand Dairy Statistics published by Dairy NZ is a comprehensive and regularly updated source of data for New Zealand dairy cattle. This data source means that regular updating of values for yield and milk protein % is possible. Moreover, there is potential in the future to include regional, seasonal, breed or age effects in the model.

This review recommends that the current value be updated annually from New Zealand Dairy Statistics (DairyNZ) with milk yield corrected for milk density (i.e. converted from litres to kilograms). The most recent P value derived from the 2011/2012 season is 3.71%CP (corrected for milk density). Regional P values are also available from the Dairy Statistics

b) **N_{rm} for beef cattle.** The current model uses the same value for milk protein concentration (P) as for dairy cows (i.e. 3.77% CP is based on average herd milk yield (litres) and protein yield (kg) data from New Zealand Dairy Statistics for the season 2010/11). It has not been corrected for milk density (1 litre milk = 1.03kg). After correction this value would be 3.66% CP (36.6gCP/kg milk).

Compared to dairy cows there is little recent data for milk protein content in beef cows and there is no data specific to the New Zealand beef industry. Nevertheless, the current [dairy cow] P value of 3.66% CP (2010/2011 season) is higher than that reported for beef cattle in the published literature (mean 3.38%).

Furthermore, the current model assumes that beef cow milk protein percentage changes annually in line with that of dairy cows. In view of greatly different selection pressures on dairy and beef cattle and the continuing increase in dairy cow milk protein percentage over time, this assumption is difficult to justify. There is no published evidence to support the assumption that milk composition of beef cows has changed or will change over time.

This review concludes that it is not appropriate to use the same milk protein values for dairy and beef cows. It recommends that the value of 3.38% CP (per kg), which is based on beef cow data, is adopted for milk protein percentage in beef cattle and that this value remains constant over time until better data is available.

c) **N_{rm} for sheep.** The current P value of 6.00% crude protein in milk is based on pre-1990 estimates for a small-medium sized UK hill breed ewe rearing a single lamb (Clark 2008). This is higher than in the published literature. Mean milk protein concentration calculated from 14 studies (including New Zealand) published between 1975 and 2006, is approximately 5.45%. However, the data is extremely variable, ranging from 4.30 to 6.80% with a clear effect of breed type, particularly when comparing Merinos and traditional meat/wool breeds with dairy breeds.

At present it is not feasible to adequately quantify breed composition of the national or regional sheep flocks and, given the small size of the sheep milking industry, this review recommends that the model retains the current mean value of 6.0% CP across all sheep breeds until better data is available.

d) **N_{rm} for deer**. There are few studies on the protein content of milk in red deer. However, these consistently report deer milk protein percentages significantly higher (mean 7.3% CP) than the 3.66% adopted by the current model.

This review recommends that a value of 7.3% CP be adopted for deer milk protein concentration until better NZ data is obtained.

3. Nitrogen retained in wool (N_{wool})

The value for $Wool_N$ of 165gN/kg clean wool DM adopted by the current model is in accordance with the available literature.

However, the current factor of 0.75 used in the model to calculate the proportion of clean wool fibre in the fleece is lower than the value of 0.8 used by ARC (1980). This may lead to an underestimate of total N retention in the national wool yield by approximately 6%.

The current model excludes the contribution of N in non-keratin components of the fleece (i.e. wax and suint). Compared to the current model this may underestimate total N retention in the national wool yield by an additional 2%

It is recommended that the current model is changed to account for the total N content in the complete fleece (including wool fibre, wax and suint) using the value of 134gN/kg of total greasy fleece weight (ARC, 1980; AFRC 1993). The 0.75 factor may then be discarded.

4. N retained in velvet antler (N_{velvet})

In the current model the value for N_v of 12.0% antler weight is not adequately defined. This is presumed to be wet weight but it is not clear whether antler yield is expressed in kg wet weight (as harvested), processed dry weight (15% moisture content; Fennessy and Duncan, 1992) or dry matter weight. Both antler yield and N content must be expressed in the same units (i.e. dry-matter weight) or suitable conversion factors used.

The mean N_v value from studies where whole antler from red deer, wapiti or wapiti crossbreeds have been analysed, is 9.0% of antler DM.

This review recommends that the model adopts a value 9.0% velvet antler DM for all stag classes and for both red deer and wapiti.

The assumption that antler growth is constant over the growing period is valid.

The current model apportions growth over three months (≈90days). However commercial practice is to harvest velvet antler at about 65 days post casting. This review recommends that this growth period is amended to 65 days to reflect this.

Introduction

The current inventory model (Pickering 2011) estimates N_2O emissions from the total amount of N excreted in the urine and faces. This is estimated by calculating an animal's total N intake (in feed) and subtracting the amount of N retained in its tissues and products:

N excretion (kg N/month) = N intake – N retained in the animal

Where, depending on species:

$$\text{N retained in the animal} = N_{lwg} + N_{rm} + N_{wool} + N_{velvet}$$

Where:

- N_{lwg} = N retained in liveweight gain (all species)
- N_{rm} = N retained in milk (all species during lactation ♀)
- N_{wool} = N retained in fleece (sheep)
- N_{velvet} = N retained in velvet antler (deer ♂)

This review assesses the relevance and accuracy of the current values for these four nitrogen retention parameters. The current model values (as described by Pickering, 2011) are compared with those of ARC (1980), AFRC (1993), NRC (2000, 2007), CSIRO (2007) and any other published data relevant to New Zealand livestock classes and production systems. This includes identifying, where possible, the source/derivation of the current parameters to evaluate their relevance to current New Zealand conditions.

Recommendations are provided on the adequacy and application of the current N retention values and specific areas for improved accuracy are identified.

DEFINITIONS

The scientific literature relating to animal production and nutrition uses a range of terms and abbreviations to describe animal liveweight and the protein and nitrogen content of animal tissues and products. These need to be taken into consideration when reviewing the scientific literature.

Liveweight and liveweight gain

Table 1 summarises common terms, abbreviations and conversion factors relating to animal liveweight and live weight gain.

Table 1. Definitions and common abbreviations used in the scientific literature to describe animal liveweight and liveweight gain

Liveweight (LWT) Liveweight gain (LWG)	Full body weight and body weight gain of the live animal which includes the weight of the contents of the digestive tract (gut fill).
Shrunk body weight (SBW) † Shrunk body gain (SBG) Fasted liveweight (FLW) † Fasted liveweight gain (FLG)	Body weight and body weight gain of the live animal after fasting. This is intended to minimise variation in contribution of gut fill to live weight. SBW is usually applied to cattle only. SBW = 0.96 × LWT; SBG = 0.96 × LWG (Fox *et al.* 2001).
Empty body weight (EBW) Empty body gain (EBG)	Live weight of an animal excluding gut contents. Since this is impractical to measure directly, it is calculated as EBW = 0.92 × LWT$^{\phi}$; EBG = 0.92 × LWG (ARC, 1980). EBG = 0.956 × SBG (Fox *et al*., 2001)

† SBW used mainly in North America; FLW more often referred to in UK, Australia, NZ

$^{\phi}$ Inversely LWT = EBW × 1.09; LWG = EBG × 1.09 (ARC, 1980)

The concentrations of components of liveweight gain (e.g. protein or nitrogen) are calculated using the inverse of the equations in Table 1. For example, rates of empty-body gain are converted to rates of liveweight gain by multiplying by a factor of 1.09 (or dividing by 0.92) whereas concentrations of components of empty-body gain are related to liveweight gain by dividing by 1.09 (or multiplying by 0.92).

Protein and nitrogen

Table 2 summarises common terms, abbreviations and conversion factors used to describe protein and nitrogen.

Table 2. Definitions and common abbreviations used in the scientific literature relating to protein and nitrogen nutrition and metabolism

Nitrogen (N)	Chemical nitrogen content
True protein (TP)	Molecules containing amino acids containing nitrogen
Crude protein (CP)	Protein content estimated by multiplying total N content by 6.25 (or 6.38 for milk) - includes NPN
Total nitrogen (total-N)	Chemical analysis of total-N (usually by the laboratory process of Kjeldahl digestion) includes both protein and NPN. Calculated by dividing CP by 6.25
Protein nitrogen (protein-N)	N contributed only by the amino acids in protein
Non-protein N (NPN)	N contributed by nitrogenous compounds not including amino acids (e.g. ammonia, nitrate, nucleic acids, urea, creatine, creatinine etc

Animal tissues and products (e.g. milk, wool and velvet antler) contain a variety of proteins made up of different combinations of amino acids. These amino acids contain various amounts of nitrogen.

As it is cheaper to chemically analyse N content than protein content and because protein contains on average 16% nitrogen, it is usual to measure nitrogen and then estimate crude protein content by multiplying the N concentration by 6.25 (i.e. 100% divided by 16%).

This calculation is an average as different proteins contain different percentages of N. For example milk protein contains 15.7% nitrogen rather than the average of 16% present in most animal proteins (e.g. muscle).

This calculation also recognises that in addition to the N from protein, tissues and products also contain non-protein (NPN) compounds such as ammonia, nitrate, nucleic acids and urea.

Nitrogen retained in live weight gain (N_{lwg})

CURRENT MODEL EQUATIONS AND PARAMETERS

The current model (Pickering, 2011) accounts for N retained in liveweight gain for growing dairy and beef cattle, sheep and deer using the following equation:

N_{lwg} (kg N/kg lwg/month) = kg nitrogen retained in each kg of live weight gain
= LWG × N_{bt} / 100 / 1000 (Equation 30)

Where

LWG = live weight gain (kg per month)
N_{bt} = percentage nitrogen in body tissue (%)

Table 3 summarises the N_{bt} values used in the current model (Pickering, 2011).

Table 3. Current model values for percentage N in body tissue (N_{bt}).

Species	N_{bt} - % N in body tissues$^{\phi}$	Source	Definition
Dairy cattle	3.26	Not stated	Nitrogen retained in tissue (%)
Beef cattle	3.26	Not stated	Nitrogen retained in body tissue (%)
Sheep	2.60	Not stated	Nitrogen in tissue (%)
Deer	3.71	Not stated	Nitrogen in body tissue (%)

$^{\phi}$ Inadequately defined (refer to text)

However, the definition of N_{bt} varies. This is important because the information required (N_{bt}) is the *nitrogen content of live weight gain* (%N or gN/kg LWG) for each month. As sources for the data are not given (Pickering, 2011) the definition of N_{bt} in the current model is not clear.

It must be stressed that N content of liveweight gain includes not only animal product (e.g. the animal carcass) but also all non-carcass components (i.e. internal organs and associated fat depots, head, feet and hide, etc.).

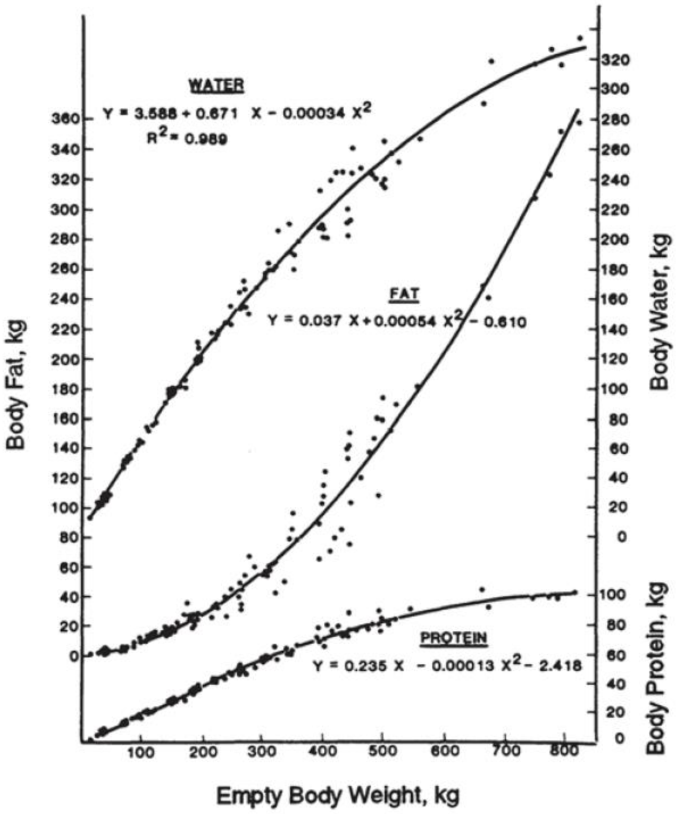
Furthermore, the chemical composition of live weight gain over a period of time is not the same as the composition of live weight at a particular time. In growing animals, different organs and tissues accumulate fat and protein at different rates and the rate of change in protein content depends on the animal's breed, sex, age, nutritional status and physiological state.

FACTORS AFFECTING CHEMICAL COMPOSITION OF LIVEWEIGHT GAIN

Factors affecting composition of liveweight gain include species, sex, breed, age, nutritional status and physiological state and these factors interact with each other.

The effect of these factors can be illustrated using data from beef cows from NRC (2000) (Figure 1).This figure shows the relationships between empty body weight with body fat and protein content in British beef steers (e.g. Angus, Hereford). Note that the empty body weight presented in Figure 1 excludes gut contents whereas the current model uses total liveweight, i.e. includes the gut contents (see Table 1).

Figure 1. Relationship between empty body weight (kg) and body fat (kg) in male castrates of British beef breeds (NRC 2000).



The slope of the line at any point indicates the rate of accretion of fat and protein at a particular body weight; the steeper the line the faster that component accumulates. This demonstrates that initially the rate of fat and protein accretion is similar. But as animals get heavier, the rate of protein accretion declines and the rate of fat accretion increases.

In addition, the rate of gain affects the proportion of fat and protein that accumulates; i.e. the rate of protein accretion decreases with higher growth rates (Table 4; NRC, 2000). This implies that protein content of gain is influenced by nutritional status.

Table 4. Relationship of stage of growth and rate of liveweight gain to body protein composition (adapted from NRC, 2000)

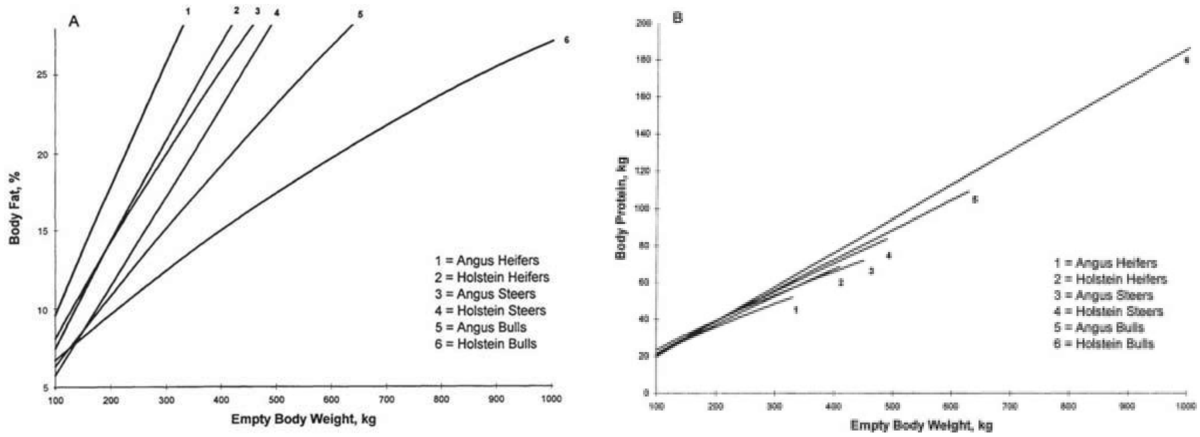
	Protein in liveweight gain %†						
Average liveweight gain (kg/day)†	Liveweight (kg)†						
	208	260	313	365	417	469	521
0.6	19.6	18.7	18.0	17.3	16.6	15.9	15.4
0.8	18.0	16.9	15.8	14.9	14.0	13.1	12.2
1.0	16.3	15.0	13.6	12.5	11.2	10.1	8.9
1.4	13.8	12.0	10.3	8.6	7.0	5.5	4.0

† NRC (2000) presents figures based on Shrunk weight average daily gain (SWADG) and Shrunk body weight (SBW). Conversion to liveweight basis was based on Fox et al., (2001): Liveweight = SBW ÷ 0.96; Empty body gain = SWADG ÷ 0.956; Liveweight gain = SWADG ÷ 0.96; Protein in liveweight gain = protein in SWADG × 0.96.

Protein accretion is fastest in bulls, slowest in heifers and intermediate in steers. Similarly protein accretion is faster in large mature sized Holsteins compared to smaller mature sized Angus (Figure 2; NRC, 2000).

Figure 2. Relationship between empty body weight (kg) and body fat (%) in Angus and Holstein heifers, steers, and bulls. Composition differs between breed and sex even when weight is the

same. A: Each type reached 28% body fat (equivalent body composition) at different weights. B: A similar plot for empty body protein; the end of the line corresponds to the weight at 28% body fat.



PUBLISHED VALUES FOR N CONTENT OF LIVEWIGHT GAIN (N_{BT})

Beef and dairy cattle N_{bt}

Growing cattle

The current model adopts a value for N_{bt} of 3.26% N (32.6 gN/kg LWG) for growing dairy and beef cattle of all classes.

ARC (1980) presents a comprehensive discussion of the body composition of cattle based on the protein content of empty body weight (EBW) and empty body gain (EBG) in about 600 animals covering a wide range of British breed types, sex, diet and rate of growth. ARC (1980) developed regression equations to calculate the protein and fat content of empty body weight and empty body gain of a standardised animal defined as a castrated male from an averaged sized breed growing at approximately 600g EBW per day (654g LWT/d). The method adopted involved considerable approximations and it was more difficult to describe protein content of gain than fat and energy content (ARC, 1980).

Table 5 presents the protein data from ARC (1980; Table 1.21) converted to mean N content of liveweight (LWT) and liveweight gain (LWG). For reasons discussed earlier, the N content of LWT and LWG are not the same and N content declines as animals get older/heavier.

Table 5. N content of liveweight (LWT) and liveweight gain (LWG) of cattle standardised to castrate males of medium sized breed gaining 654g LWT/d (calculated from ARC 1980, Table 1.21)

Empty body weight (EBW; kg)	Liveweight (kg)†	N content of liveweight (% LWT)	N content of liveweight gain (% LWG)
50	55	2.98	2.66
75	82	2.85	2.54
100	109	2.76	2.45
150	164	2.64	2.35
200	218	2.55	2.28
300	327	2.45	2.17
400	436	2.38	2.11
500	545	2.32	2.06
Mean		**2.62**	**2.33**

† LWT = EBW × 1.090 (ARC 1980)

ARC (1980) developed additive correction factors to account for a range of factors affecting body protein composition including breed, sex and rate of EBG (Table 6).

Table 6. ARC (1980) body composition correction factors for Table 5 (ARC, 1980, Table 1.22)

Factor		Percentage addition or subtraction to values in Table 5
Breed	Small	-10
	Large	+10
Sex	Female	-10
	intact male	+10
Gain	For each 0.1 kg more than 0.6 kg/day	-1.3
	For each 0.1 kg less than 0.6 kg/day	+-1.3

ARC (1980) and AFRC (1993) further developed these equations to predict net protein requirements in *liveweight gain* for growing cattle (castrates of medium sized breeds) with correction factors for breed maturity and sex. These were summarised by AFRC (1993) as:

Net protein in liveweight gain (g/d) =

$$\Delta W \{168.7 - 0.16869W + 0.0001633W^2\} \times \{1.12 - 1223\Delta W\} \times C$$

Where:

ΔW = liveweight gain (kg/d)
W = current liveweight (kg)
C = correction factor for breed maturity and sex (Table 7)

Table 7: Correction factors for net protein content in liveweight gain (ARC, 1980; AFRC, 1993)

Maturity type	Bulls	Castrates	Heifers
Early	1.00	0.90	0.80
Medium	1.10	1.00	0.90
Late	0.20	1.10	1.00

This equation and correction factors may provide an opportunity to improve the current model by accounting for effects of breed type, sex, mature liveweight and variation in cattle growth rate if the relevant data is available.

As noted earlier NRC (2000) demonstrated the relationship between rates of gain with body protein content (Table 4). Converting these figures to %N content of liveweight gain results in an overall mean of 2.14%N (21.4gN/kg liveweight gain) ranging from 0.64% for heavy animals at high growth rates to 3.14% in lighter animals at slow growth rates.

CSIRO (2007) predicts the protein composition of empty body gain (EBG) using the following equation:

Protein g/kg EBG = (a + cR) + (b – cR) / [1 + exp(-6(Z-0.4))]

[CSIRO (2007) Equation 1.31]

Where:

A	= 120 for large lean cattle breeds, e.g. Charolais, Chianina, Blonde d'Aquitaine, Limousin, Maine Anjou and Simmental; = 140 for all breeds of sheep and other breeds of cattle
Z	= current live weight /SRW (maximum value of 1 at maturity) = proportion of mature weight
R	= adjustment for rate of gain or loss = $[EBG/(4 \times SRW^{0.75})]-1$
EBG	= 0.92 × LWG in g/d
SRW	= the standard reference weight in kg.

This equation was used to predict values for the N content of empty body gain and liveweight gain at various stages of growth (P) at two rates of gain (R) (Table 8).

Table 8. Predicted values for N content in EBG and LWG in growing cattle (after CSIRO 2007)
These values also apply to sheep

	N g/kg EBG		N% LWG	
Z↓ R→	**0**	**2**	**0**	**2**
0.06	31.3	30.2	2.88	2.77
0.08	31.1	29.9	2.85	2.75
0.15	29.8	28.8	2.74	2.64
0.20	28.7	27.8	2.64	2.55
0.25	27.4	26.5	2.52	2.43
0.30	26.0	25.2	2.38	2.31
0.35	24.4	23.7	2.24	2.17
0.40	22.7	22.1	2.08	2.03
0.45	21.1	20.5	1.93	1.88
0.50	19.5	19.0	1.79	1.74
0.55	18.0	17.6	1.65	1.62
0.60	16.7	16.4	1.53	1.51
0.65	15.6	15.4	1.43	1.41
0.70	14.7	14.5	1.35	1.33
0.75	14.0	13.8	1.28	1.27
0.80	13.4	13.3	1.23	1.22
0.90	12.6	12.5	1.15	1.15
1.00	12.1	12.1	1.11	1.11
Mean	**20.0**	**19.5**	**1.93**	**1.88**

Z = current liveweight/mature liveweight
R = adjustment for rate of gain or loss representing two rates of EBG)

As the animal approaches maturity (i.e. Z approaches 1.0) the difference in protein content of gain between the two rates of gain becomes smaller. This is consistent with the expectation that gain in animals approaching maturity will contain a larger proportion of fat than in younger animals.

CSIRO (2007) uses this equation to predict the protein content of gain for both sheep and cattle (both dairy and 'small-maturity' beef breeds) at the same proportion of their mature weight.

Adult cattle

The current model (Pickering 2011) does not consider liveweight changes in adult cattle.

ARC (1980) specifies different protein composition figures for liveweight changes in adult cattle, i.e. pregnant and lactating dairy and beef cattle which can be subject to cyclical periods of weight loss and gain.

An analysis of 22 Holsteins (12 of which were pregnant) gave the following estimates for N composition of maternal empty-body weight change (Table 9). In addition, there was evidence that protein content of liveweight change varied during lactation.

Table 9. Estimate of N content of liveweight change in Holstein cows (calculated from ARC, 1980).

Empty body weight (kg)	Liveweight (kg)†	N content of liveweight change (%)
300	327	2.39
400	436	2.30
500	545	2.23
Mean		**2.31**

† LWT = EBG × 1.09 (ARC, 1980)

At 400 kg EBW (436 kg LWT) the N content of liveweight change of an adult cow is approximately 8% higher than for a growing cow (Table 5); i.e. 2.11%N compared with 2.30%N for adult and growing cows respectively.

ARC (1980) stated that no firm conclusion could be drawn for the composition of empty body-weight gain or loss in adult cattle. Estimates for N concentration of changes in adult cattle varied from 2.20% to 2.79% N for each kg of LW change. ARC (1980) recommended that a value of 2.20%N of liveweight be adopted for adult dairy and beef cattle.

Other published sources

There appears to be no recent information on protein or N content of live weight gain in cattle in the literature.

Does the model need changing - now or in future

The current model value for N_{bt} in cattle of 3.26%N is higher than values from the literature presented here.

For growing cattle the data from ARC (1980) suggests a mean N_{bt} of 2.33 %N (Table 5). Data from NRC (2000) suggests a mean of 2.14%N (Table 4). Data from CSIRO (2007) based on cattle up to 75% of their mature liveweight (Table 8) suggests a mean value of 2.06 %N. An overall mean of data from all three sources is 2.13%N.

There is not enough data at present to confirm or refute the validity of using the same value for N_{bt} dairy and beef cows.

However, there is evidence that the model could be more 'precise' by adopting an approach where protein content of gain varies with liveweight and rate of gain (which is biologically relevant in relation to breed type, mature size and sex). ARC (1980) and AFRC (1993) provides equations and correction factors through which effects of breed type, sex, liveweight and liveweight gain on nitrogen content of gain can be accounted for.

Similarly CSIRO (2007) uses equations which can account for variation in nitrogen content of gain for breed type, liveweight (proportion of mature size) and liveweight gain. The CSIRO equations are also applicable to sheep.

This would take account of most of any potential differences between dairy and beef breeds on the basis of mature size. However, we know that the body composition of dairy cows (in terms of DO%, carcass composition and conformation) is different to beef cows due to differences in body fat depots and differences size of internal organs due to selection for milk production. At present there is insufficient evidence to confirm that this results in differences in net N content of gain.

Conclusions and recommendations for N content of liveweight gain in cattle.

The current model value for N_{bt} of 3.26% N is inadequately defined and is higher than values reported in the literature.

It is recommended that the model adopts a revised value of 2.13% N per kg of liveweight gain until better data is available.

At present there is insufficient evidence to apply different values for N_{bt} in dairy and beef cattle.

It is recommended that an improved method of predicting N_{bt} is developed and validated based on the equations of ARC (1980), AFRC (1993) or CSIRO (2007) which have the potential to account for effects of breed, age, sex, mature size and growth rate on nitrogen composition of liveweight gain in growing cattle.

Sheep N_{bt}

Growing sheep

The current model adopts a value for N_{bt} of 2.60%N (26.0 gN/kg LWG) for growing sheep of all classes.

ARC (1980) analysed by regression the protein composition of empty body weight (EBW) and empty body gain (EBG) in approximately 1360 sheep from 67 data sources. The overall range in empty body weight was 10 - 45kg and Merino and Merino crosses were analysed separately. Separate equations were fitted for males/castrates and females.

Table 10 presents the protein data from ARC (1980; Table 1.8) converted to mean N content of liveweight (LWT) and liveweight gain (LWG). There was a consistent pattern of nitrogen concentration falling with increasing bodyweight. However, the separate estimates for the different sexes and, in some cases, for different breed types (e.g. Merinos and non-merinos) removed the main sources of variation in the prediction of composition.

Table 10. Nitrogen concentrations in the fleece-free liveweight (LWT) and liveweight gain (LWG) of sheep (calculated from ARC, 1980; Table 1.8).

		N content of liveweight (% LWT)		N content of liveweight gain (% LWG)	
Empty body weight (EBW; kg)	**Liveweight (kg)†**	**Males/castrates**	**Females**	**Males/castrates**	**Females**
10	10.9	2.61	2.61	2.33	2.19
15	16.4	2.51	2.42	2.25	1.98
20	21.8	2.44	2.30	2.17	1.88
25	27.3	2.38	2.20	2.13	1.81
30	32.7	2.33	2.14	2.06	1.75
35	38.2	2.29	2.07	2.06	1.69
40	43.6	2.26	2.03	2.03	1.66
45	49.1	2.23	1.98	2.00	1.61
Mean		**2.38**	**2.22**	**2.13**	**1.82**

† LWT = EBW × 1.090 (ARC 1980)

The regression equations were further developed to create two generalised equations to predict net protein requirements in fleece free *liveweight gain* for sheep (males/castrates and females) (ARC, 1980; AFRC, 1993):

Net protein in fleece free liveweight gain (g/d) =

Males, castrates $\Delta W \{160.4 - 1.22W + 0.0105W^2\}$

Females $\Delta W \{156.1 - 1.94W + 0.0173W^2\}$

Where:

ΔW = liveweight gain (kg/d)
W = current liveweight (kg)
No correction factors for breed or maturity

This equation corrected for liveweight gain, may provide an alternative for estimating N content of LWG in growing sheep by dividing the net protein in liveweight gain by the factor 6.25.

CSIRO (2007) predicts the protein composition of empty body gain for both sheep and cattle using the same equations, based on liveweight, as a proportion of standard reference weight (mature liveweight). These equations have been explained in detail above in the section on N_{lwg} in cattle (Table 10).

Therefore, the equations of CSIRO (2007) predict that N retention in LWG of growing sheep is the same as for cattle at the same proportion of mature liveweight. Based on the same criteria as for growing cattle discussed earlier (i.e. up to 75% of mature liveweight; Table 10) mean N_{bt} is 2.06%N).

Barry (1981) showed that body composition and rate of protein accretion in lambs can be influenced by nutrition. Calculated N content of liveweight gain was 2.54%N for control lambs and 3.39% N in lambs fed additional protein by abomasal infusion.

There are no additional sources for information on protein content of live weight gain, though there are numerous studies which have compared changes in carcass composition. These are not relevant to this review.

Adult sheep

The current model (Pickering 2011) does not consider liveweight changes in adult sheep.

ARC (1980) specifies different protein composition figures for liveweight changes in adult sheep, i.e. during pregnancy and lactation, but the data is based on only a few studies. For non-pregnant, non-lactating ewes, protein content of weight loss varied between 78 (O'Donovan & Elliot, 1971) and 154 g/kg EBW (Farrell et al., 1972). ARC (1980) concluded that "a representative value for protein concentration is difficult to select since directly determined values for ewes maintaining or gaining weight, of 83 to 94 g protein/kg (Rattray et al., 1974) and 78g/kg (O'Donovan & Elliott, 1971) are considerably lower than that for ewes losing weight, of 130g/kg (Heaney, 1973).

ARC (1980) concluded that if these differences are real it may be due to the fact that when gaining weight, adult sheep store protein in wool but when losing weight they are unable to draw on wool protein. ARC suggested that tentative values for the protein concentration of empty body gain and loss in [adult] ewes should be 90 and 130 g/kg respectively" (1.32 N% for LWT gain and 1.91 N% LWT loss respectively)

Estimates of nitrogen composition of empty body gain in pregnant ewes from Rattray et al (1974) are summarised in Table 11.

Table 11. Estimates of N content of liveweight gain in pregnant ewes (calculated from Rattray et al., 1974)

Empty body weight (kg)	Live weight (kg)	Protein (g/kg EBG)		N % of LWG	
		Non-pregnant	Pregnant	Non -pregnant	Pregnant
50	54.5	94	-	1.38	-
60	65.4	88	68	1.29	1.00
70	76.3	83	-	1.22	-
Mean		**88**	**-**	**1.30**	**-**

† LWT = EBW × 1.090 (ARC 1980)

No data were available for protein composition of weight change in lactating ewes.

As for cattle, CSIRO (2007) equations calculate lower N retention in LWG in adult sheep (approaching mature liveweight) than growing animals (Table 8).

Does the model need changing - now or in future

The current model value for sheep N_{bt} of 2.60%N is higher than the literature presented here.

For growing sheep, the data from ARC (1980) suggests a mean N_{bt} of 2.13 %N for males and castrates and 1.82% N for females (Table 10). Data from Barry (1981) suggests a mean of 2.54%N. Data from CSIRO (2007) based on sheep up to 75% of their mature liveweight (Table 8) suggests a mean value of 2.06 %N. An overall mean of data from all three sources is 2.04%N (LWT).

There is strong evidence for differences in composition between males/castrates and females from ARC (1980) and AFRC (1993).

As with cattle, there is evidence that the model could be more ‘precise’ by adopting an approach where nitrogen content of gain varies with liveweight and rate of gain (which is biologically relevant in relation to breed type, mature size and sex) if data is available.

ARC (1980) and AFRC (1993) provide equations and correction factors through which effects of breed type, sex, liveweight and liveweight gain on nitrogen content of gain can be accounted for. Similarly CSIRO (2007) uses equations which can account for variation in nitrogen content of gain for breed type, liveweight (proportion of mature size) and liveweight gain. These are the same equations used for cattle.

An improved model which can account for these factors may improve future flexibility to account for changes in breed types and growth rates resulting from genetic selection in response to market demands.

Until improved methods for calculating N content of gain are developed, a mean value for N_{bt} of 2.04% N on a liveweight basis is proposed.

Conclusions and recommendations for N content of liveweight gain in sheep.

The current model value for N_{bt} of 2.60% N is not adequately defined and is higher than values in the literature.

It is recommended that the model adopts a revised value of 2.04% N per kg of liveweight gain.

It is also recommended that an improved method of predicting N_{bt} is developed and validated based on the equations of ARC (1980), AFRC (1993) and CSIRO (2007) which have the potential to account for effects of breed, age, sex, mature size and growth rate on nitrogen composition of liveweight gain in sheep.

Deer N_{bt}

There appear to be no published values for protein composition of liveweight gain in deer. Studies into body composition of deer usually cite protein content of liveweight or carcass composition which is not relevant. Furthermore there is only one study (Judson 2003) by which net protein content of gain can be estimated by difference in composition of liveweight over time and those results are variable.

Judson (2003) fed 8 month-old weaner red and red×elk hybrid stags over 7 weeks in spring at winter at various nutritional levels. At the beginning and end of the study, live body composition was analysed by computerised tomography. Judson reported change in protein content per day from the difference in body protein content at the start and end of the trial. For this review it was possible to estimate percentage protein of live weight (kg) gain over the trial period.

Values were variable with some animals losing and others gaining weight over the trial period, particularly those on restricted diets. However, the data published is not adequate to estimate effects of rate of liveweight change on N content.

Judson concluded that the experiment showed significant winter-spring differences in the relative growth of fat and bone tissue in young deer. In winter, bone grew relatively faster and adipose relatively slower than in spring.

There was no significant difference between red and hybrid deer in the composition of whole body gain, but in winter there was a trend for red deer to deposit less fat than hybrids and in spring for hybrid deer to deposit less fat than red deer.

Table 12. N content of liveweight gain in red deer and red x elk stags fed *ad libitum* calculated from Judson (2003)

	N content of Live weight gain % N (kg)	
	Red deer	**Red x Elk**
Spring	2.89	4.80
Winter	2.49	2.70

This is a very crude analysis of the data and it is not possible to determine if there was a difference between deer breeds or time of year. However, it is the only data available.

The mean of all figures in Table 12 is 3.22% N (kg LWG).

NRC (2007) states that in cervid species the protein content of tissue remains constant from birth to weaning at 20.2 and 20.5% protein (of EBW) corresponding to 2.98%N and 3.01%N (of LWT) for females and males respectively (Robbins et al., 1974) and 23% (EBW) or 3.38%N (LWT) in adult white tailed deer (Robbins 1983). Composition of body weight gain was not measured.

In sheep and cattle N content of body gain is less than N content in body weight and varies with both weight and rate of gain. Although there is no data to confirm or refute that this relationship also applies to cervids, it suggests that N content of gain may be lower than the 2.98-3.38%N (mean 3.12%N) reported by NRC (2007).

There are no other published data relating to protein composition of liveweight gain in deer, relevant to New Zealand (i.e. red deer and wapiti).

Does the model need changing - now or in future

The current model value for deer N_{bt} of 3.71% N kg LWG is higher than the values in the limited data available.

There appears to be no data in the literature to support the current model value of 3.71%N. The data from Judson (2003), though limited, suggests a more reliable estimate, based on experimental data, of 3.22%N (LWG).

Conclusions and recommendations for N content of liveweight gain in deer.

The current model value for N_{bt} of 3.71% N is not adequately defined and is higher than that in the literature.

It is recommended that until more reliable data are available the value for N_{bt} of 3.22% N is adopted.

Nitrogen retained in milk (N_{rm})

CURRENT MODEL EQUATIONS AND PARAMETERS

The current model (Pickering, 2011) calculates N retained in milk (N_{rm}) on a monthly basis for lactating dairy and beef cattle, sheep and deer using the following equation:

N_{rm} (kg N/kg milk/mth) = nitrogen retained in milk

$$= Y_m \times P / 100 / 6.25 / 1000 \quad \text{(Equation 29)}$$

Where:

- Y_m = annual milk yield (kg) × monthly proportion milk yield
- P = milk protein concentration (%)
- 6.25 = constant for conversion of crude protein content of milk to nitrogen content

For all species, milk protein concentration is assumed to be constant over the complete lactation (Pickering, 2011). Similarly, for beef cattle, sheep and deer, milk yield is assumed to be constant throughout lactation and annual milk yield is averaged over months of lactation. For dairy cows, annual milk yield is apportioned monthly over lactation according to a defined 'lactation curve' (Pickering, 2011). Clark (2008) stated that monthly milk yield was based on a lactation pattern typical of a New Zealand dairy cow citing Ian Brookes, (*pers. comm*).

Table 13. Current model parameters for milk protein and yield (S. Wear, pers comm, 2013).

Species	Milk protein %	Milk N% (protein ÷ 6.25)	Annual milk yield (kg/cow)	Source
Dairy cattle	3.77$^{\phi}$	0.603	3750$^{\phi}$	NZ dairy statistics
Beef cattle	3.77	0.603	800	NZ dairy statistics
Sheep	6.00	0.960	103	Not stated
Deer	3.66	0.586	242	Not stated

$^{\phi}$ New Zealand national average for 2010/2011 season calculated from NZ dairy statistics (DairyNZ)

MILK PROTEIN % - DAIRY CATTLE

Current model values for milk protein % in dairy cattle

Pickering (2011) calculates N retained in milk (N_{rm}) using milk yield and milk protein concentrations from New Zealand Dairy Statistics which report milk yield in litres and milk protein concentration in kg CP/litre. These must be adjusted to kg by multiplying by a factor of 1.03 to account for milk density (ARC 1980; AFRC, 1993).

The current national mean value of 3.77% protein (Table 13) is calculated from dairy industry statistics for the 2010/11 season published by DairyNZ (S. Wear, pers comm, 2013). However, on further examination of the raw statistics for the 2010/11 season, it is not corrected for milk density. Corrected for milk density the value used in the model would be 3.66% CP (36.6gCP/kg).

The most comprehensive dataset of milk production in NZ dairy animals is produced annually by DairyNZ. These data provides an opportunity to accurately quote current milk protein concentration on an annual and regional basis. DairyNZ milk yield data is reported in litres and needs to be converted to kg (multiplied by 1.03) as specified in the current model.

The most recent values for milk protein (and N) content, derived from 2011/2012 statistics (Dairy NZ) are shown in Table 14. The national mean milk protein content, weighted for cow numbers and corrected for milk density, is 3.71% (kg).

Table 14: Current milk protein percentages for dairy cattle; 2011/2012 season (DairyNZ)

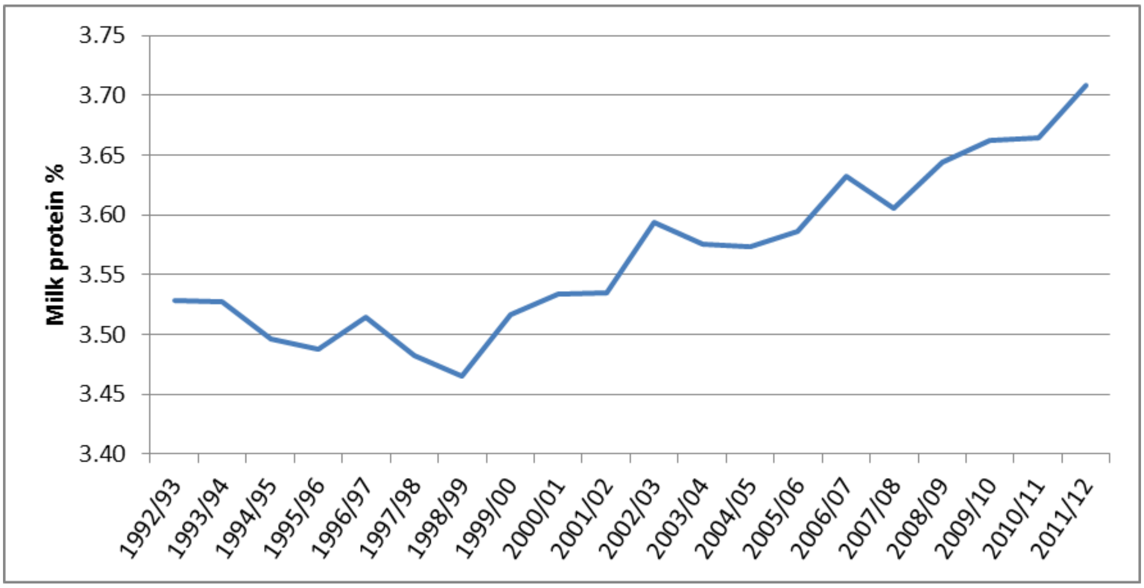
Region	*Milk Crude Protein %*[a]	Calculated % N[b]
Northland	3.63	0.58
Auckland	3.61	0.58
Waikato	3.67	0.59
Bay of Plenty	3.61	0.58
Central Plateau	3.63	0.58
Western Uplands	3.70	0.59
East Coast	3.57	0.57
Hawkes Bay	3.67	0.59
Taranaki	3.80	0.61
Manawatu	3.63	0.58
Wairarapa	3.72	0.60
Nelson/Marlborough	3.73	0.60
West Coast	3.80	0.61
North Canterbury	3.75	0.60
South Canterbury	3.74	0.60
Otago	3.73	0.60
Southland	3.77	0.60
National Average[c] 2011/2012	**3.71**	**0.59**

[a] corrected for milk density
[b] protein × 6.25
[c] weighted average (on cow numbers)

Pickering (2011) shows a consistent increase in milk protein percentage between 1990 and 2009. Figure 3 extends the data to include the years 2010-2012. This increase probably reflects changes in dairy cow genetic selection in response to payment based on milk solids rather than milk fat.

The New Zealand Dairy Statistics provide a mechanism by which the N% in dairy cow milk could be adjusted over time or by region. It also provides information from which breed and age effects on milk protein percentage could be incorporated into the model.

Figure 3. Change in national average milk protein percentage calculated from New Zealand dairy statistics (www.dairynz.co.nz).



MILK PROTEIN % - BEEF CATTLE

Current model values for milk protein % in beef cattle

Clark (2008) states that the inventory value for the annual milk yield of beef cows is based on estimated milk production of an Angus cow. Pickering (2011) states that milk protein percentages for beef cattle are calculated from New Zealand Dairy Statistics (as for dairy cows) and are adjusted from litres to kg by multiplying by a factor of 1.03. However, the milk protein % values for beef cows specified in Pickering (2011) are not the same as those specified for dairy cattle.

S. Wear (pers. comm. 2013) confirmed that the most recent national average milk protein value used for beef cattle in the model is the same as that for dairy cattle (3.77%). Note that this figure does not appear to be corrected for milk yield (litres), as described above.

Published values for milk protein content in beef cattle

There are few published reports of milk protein concentration for beef cattle breeds and none from New Zealand (Appendix 1 and Table 16). Historically, most studies into the milk composition of beef cows have measured solids-not-fat (SNF%) rather than protein concentration. Furthermore the studies reported are not directly comparable because of differences in methods of collection and measurement. Factors influencing milk composition include milk collection procedure, breed and age of cow, stage of lactation, and nutritional status (NRC 2000).

Table 15. Summary of published values for milk protein percentage in beef cattle
See Appendix 1 for details

Source	Breed	Milk crude protein percentage (per kg)
Schwulst *et al.* (1966) US	Angus (US)	3.00 (min 2.97; max 3.03)
Wilson *et al.* (1969) US	Angus x Holstein (US)	3.46 ± 0.24 (min 3.38; max 3.55).
Jeffery *et al.* (1971) US	Hereford, Angus and Galloway dams (US)	3.2 to 3.3 (1967) 3.8 to 4.0 (1968)
Mondragon *et al.* (1983) Canada	British breeds Dairy breeds Dairy x British Charolais Charolais x British Jersey x British	3.4 3.2 3.2 3.5 3.4 3..5 No significant effect of breed or calf number on milk protein%:
Butson and Berg (1984) Canada	Hereford, Charolais x, Angus x, Galloway Dairy beef crosses	3.5 ± 0.01 No breed or age differences %
Fiss and Wilton (1992) Canada	Sire breeds: Hereford Gelbveigh Pinzgauer Tarantaise Charolais Maine Anjou Simmental	 3.41 ± 0.06 2.40 ± 0.17 3.66 ± 0.17 3.68 ± 0.22 3.49 ± 0.13 3.61 ± 0.11 3.51 ± 0.09 No significant effect of breed except Gelbveigh
Masilo *et al.* (1992) US	Angus Holstein, Simmental	3.92 ± 0.3 3.25 ± 0.2 4.24 ± 0.3. Angus and Simmental significantly greater than Holstein.
Buskirk *et al.* (1995) US	Angus and Angus-Hereford heifers (US)	3.05 ± 0.10 to 3.08 ± 0.10;
Brown and Brown (2002) US	Angus Brahman	3.23 to 3.27 3.30 to 3.39

There is great variability among these published results with milk protein values varying from 2.40 to 4.24%. The mean milk crude protein % from all these studies, excluding *Bos indicus*, purebred dairy breeds and those breeds not normally found in New Zealand is 3.44%. Excluding the high 4.24% value from Simmental from Masilo et al (1992) the mean is 3.38%. This is lower than the current national average of 3.71% (on kg basis) for New Zealand dairy cows (Table 14).

Applying milk protein values calculated from dairy statistics to beef cows implies that change in milk protein concentration from beef cows has changed over time in line with that occurring in dairy cows. In the current model, beef cow milk protein % increases gradually from 3.49% (1990) to 3.77% in 2009 (Pickering, 2011). There is no published evidence to support this increase.

Though the influence of dairy genetics is increasing in the beef industry, beef genetics still have a major influence on the New Zealand beef cow herd and selection criteria for beef cattle are different to those of dairy cattle.

DOES THE MODEL NEED CHANGING - NOW OR IN FUTURE

For both dairy and beef cattle, the current model is appropriate, notwithstanding the requirement to ensure that calculation and expression of milk protein percentage is accurate and consistent (i.e. converting milk yield from litres to kg).

For dairy cattle, the New Zealand Dairy Statistics data is comprehensive and collected on an on-going basis and provides the most relevant information for New Zealand dairy cattle. This data source provides the possibility of regular updating of the protein % and the potential in the future to include regional, seasonal, breed or age data in the model.

For beef cattle, the main limits to the data are the extremely small number of studies and the lack of data specific to the New Zealand beef industry. This makes it difficult to confirm appropriate values for either milk composition or yield in beef cows. When combined with the limited selection pressure on milk composition in the beef cow there is unlikely to be any better data in the near future.

The data suggests that the increasing milk protein concentrations achieved by selection for milk solids in dairy cows is not appropriate for beef cows. The published literature suggests that a lower value of 3.38% CP may be more appropriate, and that this value remains constant over time until better data is available.

Conclusions and recommendations for milk protein content in cattle.

For dairy cattle, the current national average value for milk protein content of 3.77% based on the production year 2010/2011 does not appear to have been corrected for the conversion of milk yield from litres to kg. After correction this value should be 3.66% CP (36.6gCP/kg milk).

It is recommended that the current value be updated annually from New Zealand Dairy Statistics (DairyNZ) which need to be corrected for milk density (i.e. converted from litres to kilograms). The most recent value based on DairyNZ statistics for the 2011/2012 season is 3.71% (corrected for milk density).

For beef cattle, milk protein content in beef cows is assumed to be the same as for dairy cows, i.e. 3.71% (for the 2011/2012 dairy season). This is higher than that reported for beef cattle in the published literature (mean 3.38%).

There is no published evidence to support the assumption that milk composition of beef cows has changed or will change over time in the same way as for dairy cows.

This review concludes that it is not appropriate to use dairy milk protein values for beef cows. It is recommended that the value of 3.38% is adopted for milk protein percentage in beef cattle and that this value remains constant over time until better data is available.

MILK PROTEIN % - SHEEP

Current model values for milk protein % in sheep

Pickering (2011) calculates N retained in milk (N_{rm}) using a protein concentration of 6.00% and annual milk yield of 103 kg/ewe. Milk protein concentration is assumed to be constant over the complete lactation (Pickering, 2011). Milk yield is assumed to be constant throughout lactation and thus the annual milk yield is averaged over months of lactation.
Clark (2008) states that the source for milk protein percentage and annual milk yield were obtained from estimates based on a small-medium sized UK hill breed ewe rearing a single lamb (AFRC 1993, CSIRO 1990).

Published values for milk protein content in sheep

ARC (1980) proposed that the weighted mean value of 8.21gN/kg (5.13% CP) be accepted as representative of all sheep. This data included a range of sheep not necessarily representative of NZ sheep breeds. This protein concentration (5.13% CP) is lower that used in the current model (6.00% CP).

Table 17 Estimates of nitrogen and protein content of ewes' milk (ARC, 1980)

Source	Breed	Total N in milk (g/kg)	% Crude protein[c]
Price (1934)	Merino	7.99	4.99
Goddern & Puddy (1935)	Cheviot	9.56	5.98
El-Sokkary et al (1949)	Rohmany and Awsemy	9.24	5.78
Whiting et al (1952)	Corriedale	6.67	4.17
Bonsma (1939)	Various	8.15	5.09
Narnicoat et al (1957)	NZ Romney	8.62	5.39
Nakanishi & Tokita (1957)	Corriedale	8.70	5.44
Perrin (1958)	NZ breeds	10.75	6.72
Slen et al (1963)	Canadian Corriedale	8.11	5.07
	Hampshire	8.42	5.26
	Rambouillet	8.19	5.12
	Romonolet	7.64	4.78
	Suffolk	8.27	5.17
Ashton et al (1964)	Clun Forest	8.30	5.19
Camelesa et al (1964)	Merino	9.61	6.01
	Spanca	8.39	5.24
Bouchard & Brisson (1969)	Suffolk: North Country Cheviot	7.34[a]	4.59
Poulton & Ashton (1970)	Clun Forest	9.24[b]	5.78
Zdanowski et al (1970)	Not specified	9.42	5.89
Kataoka & Nakae (1971)	Not specified	8.77	5.48
Sebella (1972)	Improved Valachian	9.14	5.71
Simple mean		**8.60**	**5.38**
Weighted mean		**8.21**	**5.13**

[a]NPN component 0.28g/kg
[b]NPN component 0.28g/kg
[c]N × 6.25/10

It is necessary to ensure that in calculating total N retention that both milk composition and milk yield are also expressed on a per kg basis. It is also necessary to be consistent in expressing protein content as crude protein rather than true protein so as to include as NPN in milk as it is relevant to calculation of N retention in milk.

CSIRO (2007) reviewed the ARC (1980) values to convert milk crude protein into true protein for calculating metabolisable protein requirements for milk production. As these ignore NPN which is relevant to the current N retention model, these figures have not been reported here.

Other published values for protein concentration in ewes' milk are summarised in Table 18 and Appendix 2. All studies cite protein concentrations calculated from Macro-Kjeldahl N estimation (i.e. crude protein).

Table 18. Summary of published values for milk crude protein content of ewes' milk
See Appendix 2 for details

Reference	Breed	Milk crude protein percentage (kg basis)
Rattray *et al.* (1975)	Romney x Dorset Horn	5.07
Geenty (1979)	Romney, Corriedale, Dorset, Romney×Dorset, Dorset×Romney (mixed age multiparous)	4.7 – 4.9
Cowan *et al.* (1980)	Finnish Landrace x Dorset Horn (twin suckling)	5.18 – 5.48
Bencini and Purvis (1990)	Merino (two genotypoes) with single lamb)	4.85 ± 0.07 (SE); min 3.79; max 6.75
Snowder and Glimp (1991)	Rambouillet, Columbia, Polypay, and Suffolk (3-7yr-old multiparous)	5.38 (single suckling) 5.57 (twin suckling)
Peeters *et al.* (1992)	Suffolk Texel Finnish Milksheep Finn x Suffolk F2 (Finn x Suffolk) F2 xTexel	5.01 ±0.07a 4.53 ±0.16b 5.16 ±0.31ab 4.85±0.08ab 4.70± 0.08b 4.71±0.09b
Sakul and Boylan (1992)	Dorset (D), Finnsheep (F), Lincoln (L), Rambouillet (R), Romanov, Suffolk , Targhee , and three crossbreeds (F×L), (D×R), (F×L) × (D×R),	Overall mean 5.8 Dorset, Romanov, Dorset x Rambouillet highest at 6.1% Finnsheep lowest at 5.4% Significant differences among breeds at 30 days post-partum
Knight *et al.* (1993)	Poll Dorset (Commercial sheep-milking flock)	5.28 (range 5.01 – 5.49) No effect of suckling/milking treatment
Bencini and Knight (1994)	Poll Dorset (Commercial sheep milking flock)	6.72
Knight and Gosling (1995)	Poll Dorset (Commercial sheep milking flock)	6.26 (range 6.15 – 6.40)
Gosling *et al.* (1997)	Poll Dorset (Commercial sheep milking flock)	6.80 (range 5.90 – 7.44) over lactation
Bencini and Pulina (1997)	Dorset East Friesian Finn Merino Romney Suffolk **Overall mean**	6.50 6.21 5.40 4.85 5.50 5.80 **5.71**

Reference	Breed	Milk crude protein percentage (kg basis)
Muir *et al.* (2000)	East Friesian Finn x Romney Romney **Mean (over all breeds)**	5.8a 6.0b 6.2ac **6.0**
Pavić et al. (2002)	Travnik (dairy sheep breed)	5.90 (range 5.47 – 6.46) over lactation Protein concentration increased over lactation
Peterson *et al.* (2006)	Romney	4.4; 4.3 for triplet and twin suckling ewes respectively No effect of suckling treatment.

Milk protein concentration appears to have increased since the earliest studies cited here which may be a serendipitous effect of selection for increased lamb growth rates.

It also appears that milk from sheep breeds bred for dairy production also has consistently higher milk protein content (e.g. Flock House Poll Dorset ewes: mean 6.2-6.8%).

FACTORS AFFECTING MILK PROTEIN CONCENTRATION IN SHEEP

The data summarised in Table 18 and Appendix 2 clearly identifies a breed effect on milk protein concentration. Dairy type sheep breeds generally have higher milk protein concentration than traditional meat/wool type breeds as a result of selection for cheese production (Bencini and Pulina 1997). In comparison, Merinos appear to produce milk with relatively low protein concentration compared to other breeds.

Nutritional status is also known to affect sheep milk yield although protein concentration is not affected (Muir *et al.* 1998, 2000).

Studies have also reported no significant difference in milk protein composition of ewes suckling single or twin lambs (Snowder & Glimp, 1991) and ewes suckling twin and triplet lambs (Peterson *et al.*, 2006).

DOES THE MODEL NEED CHANGING - NOW OR IN FUTURE

The current model value of 6.0% crude protein in milk is based on pre-1990 estimates for a small-medium sized UK hill breed ewe rearing a single lamb (Clark 2008) and appears to be higher than that reported in the scientific literature. However, there is great variability in milk protein concentration in the literature due to differences in experimental methods such as animal management, milk collection and measurement.

Mean milk protein concentration from studies published between 1975 and 2006, including several from New Zealand (Table 18), is approximately 5.45% CP. However, the data is extremely variable ranging from 4.30 to 6.80% with a clear effect of breed type, e.g. Merinos (mean≈4.85%), 'dairy' breeds (mean≈6.28%) and traditional meat/wool and composite breeds (mean≈5.25%).

The standard animal defined by Clark (2008) may no longer be appropriate because of changes in breed composition of the New Zealand sheep flock. A more representative "national" mean milk protein percentage would be weighted for numbers of sheep from each breed type, e.g. Merinos, dairy breeds and traditional (meat/wool) breeds.

However, it is not possible to assess the influence of breed on the average milk composition of the national flock due to widespread crossbreeding between dairy, merino and traditional breeds to meet different production requirements. Furthermore, in 2012, Merinos comprised less than 5% of the national sheep flock (Beef+Lamb NZ, 2013) and there are no reliable data on the number of dairy sheep currently in New Zealand.

Similarly, the influence of breed type on milk production regionally would be impossible to assess due to lack of information on regional breed composition and movement of sheep between regions.

These factors make it difficult to justify a change from the current model value of 6.00% crude protein specified by Clark, (2008) until better data is can be collected.

Conclusions and recommendations for milk protein content in sheep.

For sheep, the current national average value for milk protein content of 6.00% based on pre-1990 data is higher than that in more recent studies including those from New Zealand (5.45% CP). However, more recent data in the literature is highly variable due to experimental methods and breed differences.

It is recommended that until better data is available, the current value of 6.0% CP specified by Clark (2008) is retained for all ewes.

MILK PROTEIN % - DEER

Current model values for milk protein % in deer

Pickering (2011) calculates N_{rm} for deer using a milk protein value of 3.66% and an annual milk yield of 242 kg/hind. Clark (2008) cites the origin of milk yield as Mulley and Flesch (2001). Milk yield and composition is assumed to be constant throughout lactation. Hind milk yield is assumed to have remained the same from 1990 to 2009 (Pickering 2011). No source for milk protein content is given.

Current model values for hind annual milk yield and lactation length have recently been updated (November 2013) following recommendations by Bown *et al.* (2012) to 204 litres per hind (average yield of 1.7 litres/day) and lactation length of 120 days.

Published values for milk protein content in deer

There are few published values for milk protein or nitrogen content in hinds, particularly for red deer and wapiti/elk. However there is consistent evidence that the mean protein concentration of deer milk is significantly higher than that of sheep and cattle (Table 19 and Appendix 3).

Table 19. Summary of published values for crude protein content of milk from deer
See Appendix 3 for details

Reference	Breed	Milk crude protein percentage (kg basis)
Arman *et al.* (1974)	Red deer (Scottish)	7.39 (range 7.14 to 8.59) over lactation Milk protein % increased over lactation
Mueller & Sadleir (1977)	Black-tailed deer (*Odocoileus hemionus columbianus*)	Mean ≈9% (min 7% at week 2; max 11% at 24 weeks of lactation) Milk protein % increased over lactation

Krzywinski *et al.* (1980)	Red deer (Poland)	6.63 (range 5.83 to 7.34)
Robbins *et al.* (1981)	"Elk" (*Cervus elaphus nelson*)	Mean 6.2% over first three months of lactation
Loudon *et al.* (1984)	Red deer (Scottish)	7.2 to 8.1
Kozak *et al.* (1995)	Wapiti (*Cervus elaphus subspecies) Canada*	Mean ≈7.7% (min 7.0 at week 3; max 8.5% at week 13 of lactation) Milk protein % increased over lactation
Landete-Castillejos *et al.* (2000)	Iberian red deer (*Cervus elaphus hispanicus*)	7.6%; (min 6.3%; max 8.8 %) over lactation Milk protein % increased over lactation
Landete-Castillejos *et al.* (2003)	Iberian red deer (*Cervus elaphus hispanicus*)	5.85 over lactation
Gjøstein *et al.* (2004)	Reindeer (*Rangifer tarandus*)	Mean 9% over lactation
Gallego *et al.* (2006)	Iberian red deer (*Cervus elaphus hispanicus*)	6.85 % (min 6.3%; max 7.4%) over lactation Milk protein % increased over lactation
Vithana *et al.* (2012)	NZ Red deer (*Cervus elaphus*)	Mean of pooled milk samples from one farm 8.8±0.13%

Across the nine studies involving red deer or wapiti, milk protein levels range from 5.83 to 8.8% with an overall mean of 7.3%. This is considerably higher than the current value of 3.66% currently used in the model for deer milk protein %, and consistently higher than milk protein values reported earlier for other farmed ruminants in New Zealand (dairy cows, beef cows and ewes).

These studies also found that in deer, milk protein percentage typically increases over lactation as milk yield declines. As these changes were generally linear over lactation an average value over lactation seems appropriate.

DOES THE MODEL NEED CHANGING - NOW OR IN FUTURE

There are a few studies on the composition of milk in red deer and wapiti. However, these all consistently report milk protein percentages significantly higher than that adopted by the current model.

The published data strongly suggest that the value for milk protein concentration should be amended to 7.3% CP but more data would be beneficial, particularly in relation to New Zealand deer.

Conclusions and recommendations for milk protein content in hinds.

For hinds, the current value for milk crude protein content of 3.66% is significantly lower than that consistently reported by overseas and New Zealand studies of red deer, wapiti and other deer species.

It is recommended that a value of 7.3% CP is adopted which reflects current published data, until more specific data relevant to New Zealand deer is available.

N retained in wool (N_{wool})

CURRENT MODEL EQUATIONS AND PARAMETERS

The current model estimates N retained in wool (N_{wool}) by first calculating total N retained in the entire national wool clip. This is then adjusted to a value per animal per month based on national sheep population statistics (Pickering, 2011)

N_{wool} (kg N/head/mth) = Nitrogen retained in wool (kg N/head/month)

$$= (Wool_{total} \times 0.75 \times Wool_N) / Population \qquad \text{(Equation 40)}$$

Where:

$Wool_{total}$ = National wool yield (kg)

$Wool_N$ = Nitrogen in wool (decimal)

Population = Total population of all sheep classes

Pickering (2011) specifies the value for nitrogen retained in wool ($Wool_N$) used in the model as 0.165 (16.5%). While no source is quoted it matches the ARC (1980) value for $Wool_N$ as 165gN/kg dry matter of cleaned wool fibre (i.e. keratin).

The wool value used in the model is greasy wool weight rather than clean wool weight yet the nitrogen content of wool seems to be expressed per unit of clean wool. A factor of 0.75 is used to account for the proportion of clean, wool fibre dry-matter (keratin) in the greasy fleece.

PUBLISHED VALUES FOR N CONTENT IN WOOL ($WOOL_N$)

N content of clean wool fibre

The small number of values reported for the nitrogen content of clean wool are similar with a value of 165gN/kg dry matter of cleaned wool fibre (Appendix 4 and Table 20).

Table 20. Summary of published values for N content of wool and fleece
See Appendix 4 for details

Source	Breed	N content of clean wool fibre % DM
Graham *et al.* (1949)	Unknown	16.2
Corfield and Robson (1955)	Australian Merino	16.35
Reis and Schinckel (1964)	Merino, Border Leicester x Merino	16.2
Paladines *et al.* (1964)	Unknown	16.85
ARC (1980)	"British coarser-woolled breeds"	16.5

There is no evidence that N content of clean wool fibre is affected by sex, age, breed or nutritional status of the animal.

Proportions and N content of fleece components

The greasy fleece contains three fractions, the wool fibres, suint (the secretion of the sweat glands) and wax (the secretions of the sebaceous glands), all of which contain N. The size of the relative proportions of each of these fractions in the fleece is extremely variable and affected by breed, nutrition and weather (ARC, 1980).

ARC (1980) calculated representative values of the proportions and chemical composition of these components for British sheep breeds (Table 21).

Table 21. Representative values for the chemical composition of the fleece and its components in British sheep breeds (ARC, 1980)

Component	Relative proportions	N content (g/kg dry matter)
Wool fibre	80	165
Wax	12	1.5
Suint	8	27
Total Fleece	100	134

From these figures it appears that approximately 98% of N in the greasy fleece is in the wool fibres and the remaining 2% is in wax and suint. This means the effect of the variability in the relative proportions of the three components on the nitrogen content of the fleece will be very small except when comparing Merino and traditional British breeds. In Merino animals, ARC (1980) found that wax may form 30% of a fleece and can differ in composition to the British coarser-woolled breeds. This is likely to be of limited importance at present as fine wool comprises only about 7% of the total wool clip (Beef+Lamb NZ, 2013). This could become more important if the model moves more regional/production system approach and it is possible to isolate Merino wool data.

However, the assumed proportion of clean wool fibre in the fleece may have large effects on N_{wool} as the model currently uses 0.75 and ARC (1980) uses 0.80.

As an example, using a $Wool_N$ value of 0.165, the 2007 annual wool yield and 0.75, results in 2693 kg N retained in the total wool clip. If the 0.75 factor changes to 0.8 then the corresponding figure is 2872 kg N, a difference of 179 kg N or approximately 6% (Table 22).

Table 22. Estimates of N retention in the total national wool yield using different factors to account for the composition of the fleece.

	Current model (Pickering, 2011)	Wool fibre proportion from (ARC 1980)
$Wool_N$ (ARC (1980)	0.165	0.165
Wool fibre proportion	0.75	0.80
Wool yield 2007 (Pickering, 2011)	21760	21760
N retained per year	2,693	2,872

Irrespective of whether 0.75 or 0.80 is used for wool yield, the model calculates N retained in the total wool clip on the basis of clean wool dry matter. It excludes the N content of wax and suint which, though small, is relevant to the calculation of N retention and N_2O emissions.

ARC (1993) calculated metabolisable protein requirements for wool growth based on the protein content of complete fleece (including fibre wax and suint) and using a crude protein content of 800g/kg fleece - equivalent to 13.4% N in the total fleece (Table 21).

DOES THE MODEL NEED CHANGING - NOW OR IN FUTURE

The current value for $Wool_N$ of 16.5% clean wool dry matter is in accordance with published values and appears to be the same regardless of breed, sex, age and nutritional status.

ARC (1980) appears to provide the only reliable value for the proportion of wool fibre in the greasy fleece (0.80) and this is greater than that used in the current model (Pickering 2011). This has the potential to underestimate N retention in the national wool yield by 6%.

The proportion of wool fibre in the whole fleece is considered to be constant amongst most breeds with the main difference being between the British coarse woolled breeds and Merinos which have higher wax content. Under current conditions this appears to be largely irrelevant due to insufficient data on the proportion of Merino and non-Merino fleeces in the national wool clip.

By converting the national wool clip to a clean dry wool weight, the model excludes the contribution of N in wax and suint to total N retention in wool. This may underestimate N retention in wool by an additional 2%.

By adopting the approach of ARC (1993) using a value for $Wool_N$ of 13.4% of total greasy fleece, and omitting the proportion (yield) factor, these sources of error could be eliminated.

It may be appropriate to evaluate and monitor the contribution of Merino and non-Merino wool to the national wool yield to determine whether additional information on differences between Merino and non-Merino wool are required to improve the accuracy of the model. This may become important if the model moves to a regional or production system basis.

Conclusions and recommendations for $Wool_N$

The value for $Wool_N$ of 165gN/kg clean wool DM adopted by the current model is in accordance with the available literature.

The current factor of 0.75 used as the proportion of clean wool fibre in the fleece in the current model is lower than the value of 0.8 used by ARC (1980). This may underestimate total N retention in the national wool yield by approximately 6%.

The current model $Wool_N$ value of 165gN/kg clean wool DM excludes the contribution of N in non-fibre components of the fleece (i.e. wax and suint). Compared with the $Wool_N$ value of 134gN/kg total greasy fleece (AFRC, 1993) this may underestimate total N retention in the national wool yield by an additional 2%.

It is recommended that the current model is changed to account for the N content in the complete fleece (including wool fibre, wax and suint) using a $Wool_N$ value of 134gN/kg total fleece (ARC, 1993). The 0.75 factor may then be discarded.

N retained in velvet antler (N_{velvet})

Velvet antler is defined as growing antler which contains an abundant blood and nerve supply and has a fully intact skin with a covering of soft fine hair. Hard antler is the antler when growth (including N accretion) has ceased, the antler has calcified and the skin, nerve and blood supply are no longer functional. Only growing velvet antler is metabolically active with consequences for N metabolism, excretion and N_2O emissions.

Velvet antler is usually harvested (cut off) around 65 days after the antler buttons from the previous set are cast (drop off), and before antlers begin to calcify significantly.

CURRENT MODEL EQUATIONS AND PARAMETERS

The current model (Pickering, 2011) calculates N retained in velvet (N_{velvet}) in stags over 1 year of age, i.e. stags 1–2 years old, stags 2–3 years old; and mixed age and breeding stags (Pickering, 2011).

N_{velvet} is calculated from the total antler yield per animal and the N content of velvet (N_v) using then following equation:

$N_{rvelvet}$ (kg N/head/mth) = nitrogen retained in velvet

$$= V \times N_v / 1000 \qquad \text{(Equation 48)}$$

Where:

V = velvet yield (kg/mth)

= annual velvet yield per head × monthly proportion of velvet growth (0.33)

N_v = nitrogen in velvet

Pickering (2011) specifies that an average of 3.0 kg of antler is grown per animal over three months. It is assumed that growth is constant over the three month period and the N content of velvet (N_v) is 12% of antler weight.

No sources for these specified values are cited by Pickering (2011). It seems likely that antler yield is expressed in kg wet weight (as harvested) as this is how it is typically sold, rather than as processed dry weight (15% moisture content; Fennessy and Duncan 1992) or dry matter weight.

This is important as yield and composition are expressed in different terms in different studies in the literature.

PUBLISHED VALUES FOR N CONTENT OF VELVET ANTLER (N_V)

There are few published reports on the nitrogen content of deer velvet (Table 23 and Appendix 5) and these are not directly comparable because of differences in the way measurements were made.

Fennessy and Duncan (1992) reported that N_v ranged from 7.8 to 9.3% antler DM from a small number of top grade NZ Red deer, Wapiti, Sika, Rusa and Fallow.

Table 23. Reported nitrogen content (N_v) of velvet antler (% of antler dry matter).
See Appendix 5 for details

Source	Species	Age (years)	Harvest date (days after casting)	N content (% antler DM)
Fennessy & Duncan (1992)[a]	NZ Wapiti	-	-	8.8 (range 8.3-9.7)
	NZ Red top grade	-	-	8.4 ± 0.51 SE
	NZ Red 2yr old	2	55	7.8 ± 0.07 SE
	NZ Sika	-	-	8.4 (range 7.9-8.9)
	NZ Fallow	-	-	9.3 (range 9.1-9.6)
	Australian Rusa	-	-	8.6 (range 8.3-8.8)
Sunwoo *et al.* (1995)[b]	North American Wapiti	4	65	9.3 (skinned antler)
Jeon *et al.* (2004)[b]	Korean Wapiti	-	-	13.6 (velvet skin only)
		-	-	9.4 (velvet core only)
Wang *et al.* (2004)[bc]	Northeast Wapiti	-	-	9.2
	Northeast Sika	-	-	9.2
	Northeast Sika × Wapiti F1	-	-	8.9
	Northeast Wapiti× Tianshan Wapiti F1	-	-	9.6
Jeon *et al.* (2006)[b]	Spotted deer (*Cervus nippon*)	5-6	55	9.9
Jeon *et al.* (2011)[bd]	Korean Wapiti	4-5	65	9.3
			80	9.6
			95	9.3

[a] N content as stated by authors
[b] N calculated from reported CP content
[c] no significant difference in CP content between species
[d] no significant difference in CP between harvest date

Five studies reported crude protein content of whole antlers or sections of antlers from various deer species. N_v values presented in Table 23 and summarised here, are estimates of N content of whole antlers on a DM basis as calculated from the data reported in the individual studies.

From Sunwoo et al. (1995) the estimated mean N content of *whole skinned antler* from 4 year old North American Wapiti stags 65 days after casting was 9.3% on a dry matter basis.

From Jeon et al (2004) estimated mean N content of velvet antler skin and velvet antler core (skinned antler) of Korean Wapiti is 13.6% and 9.48% on a DM basis respectively. The higher proportion of N in velvet skin in this study suggests that the 9.3% N for whole antler calculated from Sunwoo et al (1995) may be an underestimate of N content of whole antler.

Estimates of N_v from Wang et al (2004) ranged from 8.91 to 9.61% velvet DM in Wapiti, Sika and their F1 crossbreeds but there was no significant difference in antler crude protein content between species.

Mean whole antler N_v estimated from sectioned antlers from 4-6 year old spotted deer (*Cervus nippon*) under 4 dietary protein treatments was 9.9% on a DM basis, with no effect of diet (Jeon et al 2006).

Jeon et al (2011) found that harvesting at 65, 80 and 95 days after casting in 4-5 year old

Korean Wapiti stags had no effect on antler composition, with estimates of N_v for whole antler ranging from 9.34-9.68 %DM.

Variation in N content within antler sections

The antler is a rapidly growing and differentiating tissue at the stage when it is harvested as a high quality antler (Fennessy and Duncan, 1992). This is reflected in differences in chemical composition between different parts of the antler (Fennessy & Duncan, 1992; Sunwoo et al 1995; Jeon et al 2006; 2011). These studies reported increasing N content of antler sections along the antler from the base (lowest concentration) to the growing tip (highest concentration) (Table 24).

Table 24. Reported nitrogen content (N_v) of velvet antler sections (% of antler dry matter).
See Appendix 5 for details

Source	Species	Age (years)	Harvest date (days after casting)	N content (% antler DM)			
				Whole antler	Tip	Middle	Base
Fennessy & Duncan (1992)[a]	NZ Red	2	55	7.8±0.07	11.8±0.3	7.6±0.3	6.9±0.5
Sunwoo et al (1995)[b]	North American Wapiti	4	65	9.3[d]	11.1[d]	9.14[d]	7.88[d]
Jeon et al (2006)[b]	Spotted deer	5-6	55	9.9	11.2	9.6	8.8
Jeon et al (2011)[c]	Korean Wapiti	4-5	65	9.3	10.6	9.1	8.3
			80	9.6	11.2	9.7	8.3
			95	9.3	10.5	9.3	8.1

[a] N content as stated by authors
[b] N calculated from reported CP content
[c] no significant difference in CP between harvest date
[c] skinned antler

Factors affecting velvet N content

Reports suggest that there is little difference in the N content of velvet antler between breeds (Table 23) although there is a suggestion that there may be slightly higher N content in antlers of larger older animals, particularly when comparing red deer and wapiti (Table 24). It is well known that older, larger deer generally have larger antlers at the same age (Fennessy and Suttie 1985).

At the time of commercial harvesting (approximately 65 days after casting) velvet antlers of older, larger animals appears to have more antler mass in the upper beams and growing points than that those of smaller, younger animals. These distal sections have been shown to have higher concentrations of N than proximal sections (Table 24) which may partially explain the apparently greater N concentrations in whole antlers of older larger animals. However, this hypothesis cannot be confirmed from existing data (Table 24).

Three NZ studies found no effect of nutritional status on rate of velvet antler growth in red deer (Fennessy and Suttie 1985; Muir 1985, Muir *et al.* 1987).

The current model assumes that antler growth is constant over the growing period. Muir et al (1987) reported that in red deer growth in antler length follows a sigmoidal (Gompertz) growth curve. Growth in length and weight occurred most rapidly between 28 days and 122 days after casting with the rate of growth (weight) being linear up to the typical velvet harvest at 65 days.

Fennessy and Duncan (1992) stated that stage of growth had a very marked influence on gross chemical composition in 2 year old NZ Red stags. They reported significant differences over time in mineral, lipid and ash components. However they did not report antler N composition.

Only one study reports protein content of antlers over time (Jeon *et al.*, 2011). There was no difference in antler protein content between 65, 80 and 95 days after casting. No studies have reported antler protein or N content earlier to 65 days post-casting.

These data provide no reason to contradict the current model's assumptions that growth rate and composition of velvet antler remains constant throughout the growth period.

DOES THE MODEL NEED CHANGING - NOW OR IN FUTURE

The current model (Pickering, 2011) calculates net retention of N in whole, harvested velvet antlers over three months based on the assumption that the antler grows at a constant rate and that the mean N content of antler is constant over that time, for all species and for all age classes.

The current model uses a value for N_v of 12% of antler weight. It is assumed that antler yield is expressed in kg wet weight (as harvested) rather than processed dry weight (15% moisture content; Fennessy and Duncan, 1992) or dry matter weight. The crude mean of N_v values from all studies cited (Table 23), where whole antler from red deer, wapiti or wapiti crossbreds crosses has been analysed, is 9.0% of antler DM. This means the model is likely to significantly over-estimate N content in velvet antlers. It is recommended that the current model adopts a N content of 9% of antler DM but data on DM% is needed to correct N content from dry weight to fresh weight (same units as the model).

The current model calculates N retention in velvet over three months (≈90 days). Current commercial practice is to harvest antlers around 65 days after casting. It is suggested that the model be changed to reflect this true growth period.

The current model assumes that antler growth (in terms of weight) is constant (i.e. linear) over the whole growth period. This appears to be supported by the literature, particularly Muir *et al.*, (1987).

The current model assumes that the N content of whole antlers is the same for all stag age classes. There are trends in the published data (Table 24) which suggest that the N content of velvet antler is greater in older larger animals particularly when comparing red deer and wapiti. However, there is no definitive data to support that hypothesis. Therefore until better data is available the current assumption remains valid.

The current model assumes that velvet yield and N content of velvet in stags in deer since 1990. There is no published evidence that N content has changed over that period or will in the future. However, selection for increased antler weight in deer breeding programs has continued since 1990. It is recommended that the average yield for velvet antler is reviewed and adjusted. A more precise model may also take into consideration that older larger animals have greater velvet yield (Fennessy and Suttie, 1985).

Conclusions and recommendations for deer N_v

In the current model the value for N_v of 12% antler weight is inadequately defined and is at variance with the available literature.

It is recommended that the model adopts a value of 9.0% of velvet DM for all stag classes and for both red deer and wapiti. Antler yield must be therefore be expressed as a dry matter weight or suitable factors used to convert N_v to wet weight basis. The assumption that antler growth is constant over the growing period is valid.

The current model apportions growth over three months (≈90days). However, commercial practice is to harvest velvet antler at about 65 days post casting. It is recommended that the growth period is adjusted to reflect this.

In view of expected increases in antler yield due to genetic selection since 1990 it is recommended that antler yield and its relationship with age/size of red deer and wapiti be reviewed with a view to improving the model's precision in predicting N retention in velvet antler.

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Appendices

Appendix 1. Summary of published values for milk protein percentage in beef cattle

Source	Breed	Crude protein concentration	Comments
Scwulst et al (1966)	Angus (US)	Mean 3.00% protein (min 2.97; max 3.03)	Trial to evaluate oxytocin for milking experiments (on significant effect of treatment on milk protein percentage).
Wilson et al (1969)	Angus x Holstein (US)	Mean protein level 3.46% ± 0.24 (min 3.38; max 3.55%). No effect of feeding level, cow body size or calf sex on milk protein %	Effect of cow feeding level (85% and 115% of NRC 1963 requirements) on milk production and calf performance
Jeffery et al (1971)	Hereford, Angus and Galloway dams (US)	No significant effect of dam breed on milk protein percentage Results varied from 3.2 to 3.3% in one year and 3.8 to 4.0% in the next year.	Overall average of tabulated means 3.6%
Mondragon et al (1983)	10 year Canadian study investigating British beef, Charolais and dairy breeds and their crosses.	Significant increase in milk protein % during lactation: mean 3.4% (min 3.2; max 3.6) No significant breed or calf number effect on milk protein%: British breeds 3.4 Dairy breeds 3.2 Dairy x British 3.2 Charolais 3.5 Charolais x British 3.4	Study over 10 years "…breed differences in composition of milk have not been well defined." Protein percentages increased during lactation. No significance effect of calving status (1, 2, or 3) calves on milk protein %.
Butson & Berg (1984)	Hereford, CharolaisxAngusxGalloway Dairy beef crosses (Canada)	No breed or age differences in percent protein 3.5 ± 0.01	
Fiss & Wilton (1992)	Purebred Herefords, crossbreeds sired by Gelbveigh, Pinzgauer & Tarentaise, (small breeds), crossbreeds sired by Charolais, Maine Anjou, Simmental (large breeds)	Mean milk protein % ± SE Sire: Hereford 3.41 ± 0.06 Gelbveigh 2.40 ± 0.17 Significantly less than other sire breeds Pinzgauer 3.66 ± 0.17 Tarantaise 3.68 ± 0.22 Charolais 3.49 ± 0.13 Maine Anjou 3.61 ± 0.11 Simmental 3.51 ± 0.09	No significant difference between breeds except for Glebveigh sired cows. Mean of tabulated means (except Gelbveigh) = 3.56%

Source	Breed	Crude protein concentration	Comments
Masilo et al (1992)	Angus, Holstein, Simmental (US)	Angus 3.92 ± 0.3; Holstein 3.25 ± 0.2; Simmental 4.24 ± 0.3. Angus and Simmental significantly higher than Holstein.	Milk composition during first 30 days lactation in primiparous cows over two years.
Brown & Brown (1993)	Angus, Brahman (US)	Calculated milk % from daily milk yield and poteen yield for cows grazed on two forage systems (Bermuda and Tall fescue pastures) Angus 3.23 and 3.27%; Brahaman 3.39 and 3.30% for bermuda and tall fescue forages respectively	Though *B. indicus* irrelevant to NZ it is interesting that milk protein percentages are similar to *B. taurus* – similar to Martinez-Velazquez et al (2010)
Buskirk et al (1995)	Angus and Angus-Hereford heifers (US)	No effect of breed or feeding treatment on milk protein % Low intake 3.08 ± 0.10; High intake 3.05 ± 0.10	High and low feeding levels

Appendix 2. Summary of published values for milk crude protein content of ewes' milk

<table>
<tr><th>Reference</th><th>Breed</th><th>Values</th><th>Comments</th></tr>
<tr><td>Rattray et al (1975)</td><td>Romney x Dorset Horn</td><td>5.07%</td><td>Combination of high and low stocking rates and early and late lambing treatments over 2 years. No significant difference in composition between treatments, years or over lactation</td></tr>
<tr><td>Geenty (1979)</td><td>Romney, Corriedale, Dorset, Romney×Dorset, Dorset×Romney (mixed age multiparous)</td><td>Mean (± SD) milk protein % (on kg basis)
<table>
<tr><th></th><th>6 weeks</th><th>9 weeks</th><th>12 weeks</th></tr>
<tr><td>Season 1 (1971)</td><td>4.7 ± 0.52</td><td>4.7 ± 0.46</td><td>4.8 ± 0.44</td></tr>
<tr><td>Season 2 (1973)</td><td>4.9 ± 0.53</td><td>4.8 ± 0.35</td><td>-</td></tr>
</table></td><td>Overall mean 4.78 (of 5 tabulated means)
No significant difference between breeds or over lactation</td></tr>
<tr><td>Cowan et al (1980)</td><td>Finnish Landrace x Dorset Horn (twin suckling)</td><td>Milk composition in first 6 weeks of lactation in ewes with differing fat reserves at lambing and at two feeding levels during lactation
<table>
<tr><td>Feeding level in pregnancy</td><td>Low</td><td></td><td>High</td><td></td><td></td></tr>
<tr><td>Feeding level in lactation</td><td>Low</td><td>High</td><td>Low</td><td>High</td><td>SED</td></tr>
<tr><td>Mean milk protein %</td><td>5.48</td><td>5.44</td><td>5.18</td><td>5.27</td><td>0.15</td></tr>
</table></td><td>High level of feeding in pregnancy reduced milk protein content in lactation, though feeding level during lactation made no difference to protein content. Overall mean 5.34% (of 4 tabulated means)</td></tr>
<tr><td>Bencini & Purvis (1990)</td><td>Merino (two genotypoes) with single lamb)</td><td>Mean milk protein % over 9 weeks of lactation 4.85 ± 0.07 (SE); min 3.79; max 6.75</td><td>No difference in milk composition between two merino genotypes. Age and liveweight of ewes did not affect milk composition</td></tr>
<tr><td>Snowder & Glimp (1991)</td><td>Rambouillet, Columbia, Polypay, and Suffolk (3-7yr-old multiparous)</td><td>
<table>
<tr><th>Days post partum</th><th></th><th>0</th><th>4</th><th>28</th><th>42</th><th>56</th><th>70</th><th>84</th><th>98</th><th>SE</th><th>Overall mean (28 days +)</th></tr>
<tr><td>Milk protein %</td><td>Single</td><td>10.1</td><td>7.2</td><td>5.7</td><td>5.2</td><td>5.1</td><td>5</td><td>5.5</td><td>5.8</td><td>0.31</td><td>5.38</td></tr>
<tr><td></td><td>Twin</td><td>11.2</td><td>6.5</td><td>5.7</td><td>5.3</td><td>5.2</td><td>5.4</td><td>5.7</td><td>6.1</td><td>0.1</td><td>5.57</td></tr>
</table></td><td>Milk protein content not affected by lamb number or breed and consistent over lactation (except greater near birth due to colostrum composition)</td></tr>
<tr><td>Peeters et al (1992)</td><td>Flemish Milksheep, Suffolk, Texel and their crossbreds</td><td>
<table>
<tr><th>Breeds</th><th>Protein %</th><th>Overall mean</th><th>4.71±0.08 (yr 1)
4.91±0.21 (yr 2)</th></tr>
<tr><td>Suffolk</td><td>5.01 ±0.07^{a}</td><td></td><td></td></tr>
<tr><td>Texel</td><td>4.53 ±0.16^{b}</td><td></td><td></td></tr>
<tr><td>Finnish Milksheep</td><td>5.16 ±0.31^{ab}</td><td></td><td></td></tr>
<tr><td>Finn x Suffolk</td><td>4.85±0.08^{ab}</td><td></td><td></td></tr>
<tr><td>F2 (Finn x Suffolk)</td><td>4.70± 0.08^{b}</td><td></td><td></td></tr>
<tr><td>F2 xTexel</td><td>4.71±0.09^{b}</td><td></td><td></td></tr>
</table></td><td>Milk composition not significantly affected by genetic and physiological effects (i.e. protein level constant over lactation and no difference between breeds between years</td></tr>
</table>

<table>
<tr><th>Reference</th><th>Breed</th><th>Values</th><th>Comments</th></tr>
<tr><td>Sakul & Boylan (1992)</td><td>Dorset (D), Finnsheep (F), Lincoln (L), Rambouillet (R), Romanov, Suffolk , Targhee , and three crossbreeds (F×L), (D×R), (F×L) × (D×R),</td><td>Overall average protein content 5.8%
Dorset, Romanov, Dorset x Rambouillet highest at 6.1%
Finnsheep lowest at 5.4%</td><td>Significant differences among breeds at 30 days post partum</td></tr>
<tr><td>Knight et al (1993)</td><td>Poll Dorset (Commercial sheep-milking flock)</td><td><table>
<tr><th>Milking/suckling treatment</th><th colspan="2">Control (Twice a day)</th><th colspan="2">Day suckled</th><th colspan="2">Night suckled</th><th colspan="2">Once a day</th></tr>
<tr><td>% protein on</td><td>Mean</td><td>SEM</td><td>Mean</td><td>SEM</td><td>Mean</td><td>SEM</td><td>Mean</td><td>SEM</td></tr>
<tr><td>26-Sep</td><td>5.88</td><td>0.20</td><td>4.91</td><td>0.21</td><td>4.72</td><td>0.23</td><td>5.43</td><td>0.33</td></tr>
<tr><td>16-Oct</td><td>4.85</td><td>0.33</td><td>4.04</td><td>0.35</td><td>4.77</td><td>0.35</td><td>5.45</td><td>0.56</td></tr>
<tr><td>23-Oct</td><td>5.44</td><td>0.11</td><td>5.35</td><td>0.12</td><td>5.37</td><td>0.12</td><td>5.19</td><td>0.20</td></tr>
<tr><td>6-Nov</td><td>5.77</td><td>1.11</td><td>5.75</td><td>0.12</td><td>5.83</td><td>0.12</td><td>5.76</td><td>0.19</td></tr>
<tr><td>Mean (of means)</td><td>5.49</td><td></td><td>5.01</td><td></td><td>5.17</td><td></td><td>5.46</td><td></td></tr>
</table></td><td>No effect of suckling/milking treatment on milk protein concentration
Overall mean protein content 5.28% (mean of cited means)</td></tr>
<tr><td>Bencini & Knight (1994)</td><td>Poll Dorset (Commercial sheep milking flock)</td><td>Mean 6.72% protein</td><td>Milk protein concentration not affected by stripping method at milking</td></tr>
<tr><td>Knight & Gosling (1995)</td><td>Poll Dorset (Commercial sheep milking flock)</td><td>Effect of milking frequency on milk protein concentration.
Protein % was higher in the milk from ewes missing a morning milking every 7 days (6.40 ± 0.08% for ewes missing a milking versus 6.15 ± 0.07% for controls; $P < 0.05$) and in the ewes milked once a day (6.3 ± 0.1% for ewes milked once a day versus 6.1 ±0.1% for ewes milked twice a day; $P < 0.01$).</td><td>Overall mean 6.26% protein</td></tr>
<tr><td>Gosling et al (1997)</td><td>Poll Dorset (Commercial sheep milking flock)</td><td>Average protein concentration increased during lactation (from 5.90 ± 0.04 at 1 month to 7.44 ± 0.08% at 5 months of lactation). Average over lactation 6.8%. Average concentration of 2-5 year old ewes = 6.63%</td><td>Older ewes have higher protein concentration but lower overall protein yield.</td></tr>
<tr><td>Bencini & Pulina (1997)</td><td>29 dairy and meat breeds</td><td>Average protein content of al 29 breeds =5.86% (max 7.30; min 4.51%)<table>
<tr><th>NZ Breeds cited</th><th>Protein %</th></tr>
<tr><td>Dorset</td><td>6.50</td></tr>
<tr><td>East Friesian</td><td>6.21</td></tr>
<tr><td>Finn</td><td>5.40</td></tr>
<tr><td>Merino</td><td>4.85</td></tr>
<tr><td>Romney</td><td>5.5</td></tr>
<tr><td>Suffolk</td><td>5.8</td></tr>
<tr><td>Overall mean</td><td>5.71</td></tr>
</table></td><td>Sources cited range from 1957 to 1994
Over 29 European, middle eastern and Australasian breeds).

Average of NZ breeds cited is 5.71%</td></tr>
</table>

Reference	Breed	Values	Comments
Muir et al (2000)	East Friesian, Finn x Romney, Romney	Breed / Protein %: East Friesian 5.8[a]; Finn x Romney 6.0[b]; Romney 6.2[ac]; Mean (over all breeds) 6.0. Figures with different superscripts are significantly different	Figures are average milk composition measured over 15 weeks lactation under a specifically managed high performance lamb system.
Pavić et al 2002	Travnik (dairy sheep breed)	Protein % Mean ± SE: Early- $5.47^a \pm 0.08$; Mid- $5.94^b \pm 0.05$; Late-lactation $6.46^c \pm 0.14$; Overall 5.9 ± 0.05	Significant change in protein composition over lactation (18.09% increase)

Appendix 3. Summary of published values for crude protein content of milk from hinds

Reference	Breed	Values	Comments
Arman et al (1974)	Red deer (Scottish)	Milk protein concentration increase during lactation Mean % 7.14; 7.63; 8.59 at 3-30 days; 31-100days and 101+ days of lactation respectively. Overall mean for 3-100days lactation = 7.39%	Protein concentration calculated from total N x 6.38 (not 6.25).
Mueller & Sadleir (1977)	Black-tailed deer (*Odocoileus hemionus columbianus*)	Mean ≈9% (min 7% at week 2; max 11% at 24 weeks of lactation) Milk protein % increased over lactation	
Krzywinski et al. (1980)	Red Deer (Poland)	Measure total milk N over 17 days, ranging from 0.93 to 1.18 %, mean 6.63%. Corresponding CP (x 6.25) = 5.83%-7.34%; mean 6.63%.	
Robbins et al. (1981)	"Elk" (*Cervus elaphus nelson*)	Mean 6.2% over first three months of lactation	
Loudon et al (1984)	Red deer (Scottish)	Milk protein concentration ranged from 7.2% to 8.1% under different nutritional planes	
Kozak et al. (1995)	Wapiti (*Cervus elaphus subspecies) Canada*	Mean ≈7.7% (min 7.0 at week 3; max 8.5% at week 13 of lactation) Milk protein % increased over lactation	Subspecies not specified
Landete-Castillejos et al (2000)	Iberian red deer (Cervus elaphus hispanicus)	Milk protein concentration increase during lactation Average milk protein composition over 34 weeks 7.6%; (min 6.3%; max 8.8 % at week 6 and 30 of lactation respectively.)	
Landete-Castillejos et al (2003)	Iberian red deer (Cervus elaphus hispanicus)	Average milk protein composition over 10 weeks 5.85%	Protein concentration remained constant over 10 week lactation and not affected by level of hind nutrition
Gjøstein et al. (2004)	Reindeer (*Rangifer tarandus*)		
Gallego et al. (2006)	Iberian red deer (*Cervus elaphus hispanicus*)	6.85 % (min 6.3%; max 7.4%) over lactation Milk protein % increased over lactation.	Mean 9% over lactation
Vithana et al. (2012)	NZ Red deer (*Cervus elaphus*)	Mean of pooled milk samples from one farm 8.8±0.13%	Red Deer at Lincoln University

Appendix 4. Summary of published values for N content of wool and fleece

Source	Breed	Values	Comments
Graham et al (1949)	"Sheep" wool	Defatted with benzene and dried *in vacuo* total nitrogen 16.2% DM "defatted" wool	
Corfield & Robson (1955)	Australian Merino	Wool nitrogen content by macro-Kjeldahl = 16.35% DM cleaned wool fibre	
Reis & Schinckel (1964)	Merino, Border Leicester x Merino	Wool nitrogen content by macro-Kjeldahl = 16.2% DM cleaned wool fibre	
Paladines et al (1964)	Breed not identified	Wool nitrogen content by macro-Kjeldahl = 16.85% DM cleaned wool fibre Cited Block & Bolling (1948) as stating that wool contains 16.8% N	The authors conclude that protein content of wool = N x 5.933 (not 6.25)
ARC (1980)	"British coarser-woolled breeds"	"Representative values" for the chemical composition of wool fibre, wax, suing and total fleece selected from various studies, which included both British and exotic breeds (e.g. Merino). $Wool_N$ = 165gN/kg DM of wool fibre which comprises 80% of the total fleece weight. N content of whole fleece (including suint and wax) = 134gN/kg (assumed to be on DM basis)	
AFRC (1993)	Breed not specified	Adapts ARC (1980) values and states wool crude protein content of 800g/kg. This value applies to whole fleece rather than cleaned wool fibre. Converting to N using 6.25 gives N content of fleece as 12.8 %. Using the figure of 5.933 (Paladines et al, 1964) N content of fleece as 13.4 % which is the figure stated for N content of whole fleece in ARC (1980)	

Appendix 5. Summary of recent studies reporting crude protein or nitrogen content of velvet antlers (% of antler dry matter).

Source	Species	Stag Age	Harvest date (days after casting)	N content (% antler DM)				Comments
				Whole antler	Tip	Middle	Base	
Fennessy & Duncan (1992)	NZ Wapiti	Not stated	Not stated	8.8 (range 8.3-9.7)				N content as stated by authors
	NZ Red top grade	Not stated	Not stated	8.4 ± 0.51 SE				
	NZ Red 2yr old	2 years old	55	7.8 ± 0.07 SE	11.8 ± 0.3	7.6 ± 0.3	6.9 ± 0.5	
	NZ Sika	Not stated	Not stated	8.4 (range 7.9-8.9)				
	NZ Fallow	Not stated	Not stated	9.3 (range 9.1-9.6)				
	Australian Rusa	Not stated	Not stated	8.6 (range 8.3-8.8)				
Sunwoo et al (1995)	North American Wapiti	4 years old	65	9.3 (skinned antler)	11.1	9.14	7.88	N content of whole antler estimated from reported CP content of sectioned, skinned antlers
Jeon et al (2004)	Korean Wapiti	Not stated	Not stated	13.6 (velvet skin only) 9.4 (velvet core only)				N calculated from reported CP content
Wang et al (2004)	Northeast Wapiti	Not stated	Not stated	9.2				N calculated from reported CP content: no significant difference in CP content between species
	Northeast Sika	Not stated	Not stated	9.2				
	Northeast Sika × Wapiti F1	Not stated	Not stated	8.9				
	Northeast Wapiti× Tianshan Wapiti F1	Not stated	Not stated	9.6				
Jeon et al (2006)	Spotted deer (*Cervus nippon*)	5-6 years old	55	9.9	11.2	9.6	8.8	N calculated from reported CP content
Jeon et al (2011)	Korean Wapiti	4-5 years old	65	9.3	10.6	9.1	8.3	N calculated from reported CP content: no significant difference in CP between harvest date
			80	9.6	11.2	9.7	8.3	
			95	9.3	10.5	9.3	8.1	